Palmer Street Development Stage 1
Waipa District Council
03-Dec-2015

Commercial-in-Confidence

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Engineering and Environmental Assessment

Interpretation and Recommendations

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Interpretation and Recommendations

Client: Waipa District Council

Co No.: N/A

Prepared by

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Executive Summary

Waipa District Council has engaged AECOM New Zealand Limited (AECOM) to undertake an environmental and engineering assessment of land owned by the Council between Palmer Street and Roche Street in Te Awamutu. During the 1950's uncontrolled fill was placed within the site and is currently occupied by 12 buildings that are used for pensioner housing. Some of the buildings have experienced settlement that has resulted in visible structural damage. Maintenance of the buildings has been deferred for several years as the extent of structural issues has not been quantified. It was also unclear if there were any environmental concerns as a result of the sites history.

In 2013 the Council commissioned a geotechnical report and an environmental report of the site. However following completion of these reports there were still questions regarding the suitability of the site for pensioner housing and what remedial works, if any, were required.

In addition to requesting information on the state of the existing structures and infrastructure the Council also requested that the current assessment address new buildings and additions.

AECOM was engaged to build on the existing information and undertake supplementary investigations in order to provide a multidisciplinary assessment that included:

- Structural assessment of buildings.
- Geotechnical assessment of ground conditions.
- Civil engineering assessment of infrastructure.
- Mapping of infrastructure.
- Environmental assessment of soil contamination.
- Planning assessment of consent requirements.

Six of the twelve buildings have experienced minor differential settlement and no structural repair is necessary. More severe settlement is in the northern and central part of the site where re-levelling by "jack and pack" methodology is recommended for three buildings. Another three buildings have been assessed as requiring underpinning with new foundations.

Ground investigations identified a shallow cover layer of sandy silt and silty sand overlying refuse. The cover layer varies in thickness from 0.3 to 1.2 m. The type of refuse encountered varied and included: glass bottles, ceramic plates, pieces of plastic and plastic wrapping, concrete, corrugated iron, wire, and shards of metal. The refuse was found to be present to a depth of up to 6 m below ground level, however the typical depth was 2 to 3 m below ground level. The natural soil underlying the fill varied with location and included silt, silty clay, sandy silt and peat.

The fill is expected to continue to settle and piles will be required for any new foundations at the site. The type of pile and the pile depth will depend on whether it is for new foundations or to underpin existing buildings. Services and pavements will also need to be designed to accommodate settlement.

The infrastructure on the site was inspected by CCTV and the locations were surveyed. The infrastructure has some signs of sagging of pipes but they are serviceable in the short term. Council mains are in better condition than laterals to buildings.

Soils used to cover the refuse contain concentrations of trace elements, including cadmium, lead and zinc, elevated above the regional background. In the case of lead and polycyclic aromatic hydrocarbons (PAH), concentrations have been identified in discrete locations in excess of the criteria of protection of human health. Whilst these are not considered reflective of average site conditions, owing to the heterogenous nature of the contaminants and extent identified, the management of site user exposure to such contamination and the underlying refuse is considered appropriate. It is considered that such management can be adequately achieved through implementation of a site management plan that outlines controls relating to soil disturbance and produce ingestion. Groundwater monitoring determined that contaminant concentrations in leachate generated from the fill and in groundwater immediately down-gradient of the fill are low and generally within the water quality requirements for potable water. While the influence of leachate is apparent in groundwater immediately down-gradient, this influence is considered minor. Overall, the leachate discharge at the site is not expected to adversely influence groundwater as a resource, or pose a potential risk to human health.

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There is no current consent for any of the leachate discharge that is occurring. A resource consent authorising ongoing leachate discharges from the site may be required from the regional council.

Recommendations

AECOM recommends that the following is undertaken:

- Development of master plan options for redevelopment including cost estimations for re-use of existing buildings and new buildings.
- Consideration on the contaminant mitigation measures (primarily raised beds and vapour barriers beneath residence) in each of the master plan options.
- Costings for each option.

In parallel with the above tasks it is recommended that discussions with the Waikato Regional Council and the Waipa District Council resource consents unit be held to confirm any consenting requirements for the site.

Once the preferred site remediation option/approach has been determined, any necessary application(s) to the respective Councils to authorise the remediation works and any ongoing discharges from the site should be made. These applications will need to include an Assessment of Environmental Effectsand any ongoing monitoring proposed.

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1.0 Introduction

The Waipa District Council owns pensioner flats on a collection of sites bounded by Palmer, Vaile and Roche Streets in Te Awamutu. Uncontrolled fill was placed on the site during the 1950's. Pensioner flats were subsequently constructed over the fill. There is visible evidence of the ground surface settling and damage occurring to some of the buildings.

AECOM New Zealand Ltd (AECOM) has been engaged by the Waipa District Council (WDC) to assess the site and advice on the repair of the buildings and infrastructure, where required, and the constraints for new development.

The assessment is multidisciplinary and includes:

- Structural assessment of buildings
- Geotechnical assessment of ground conditions
- Environmental assessment of soil contamination
- Civil engineering assessment of infrastructure
- Mapping of infrastructure
- Planning assessment of consent requirements.

This document presents the interpretation of the data and observations gathered during our investigations and provides our recommendations for future site use. This report is to be read in conjunction with:

- Palmer Street Engineering & Environmental Investigation Factual Report
- Palmer Street Contamination assessment report (DSI)

The report is structured so that each disciplines assessment and recommendations are initially reported in isolation. In Section 8.0 we discuss the interaction between the assessments and provide our overall recommendations.

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2.0 Objectives

Waipa District Council has deferred maintenance to the complex at Palmer Street. Prior to undertaking maintenance or upgrades the Council requires additional information regarding the suitability of building foundations, services and site contamination.

We understand that the Council's preferred option when commissioning our assessment is to convert the existing bedsit units into 1 bedroom apartments. This may be done either within the existing building shell or by additions to the existing buildings. Should this be viable then new units will be constructed on vacant areas of the site. Tenants will be moved one block at a time as the upgrades are undertaken progressively.

Other options are to redevelop the site with new buildings or in the most adverse outcome abandon the site. The latter is considered undesirable due to the number of people to be relocated and the sites proximity to town, doctors and supermarkets.

AECOM has been engaged by WDC to assess the extent of the existing engineering and environmental issues on the Palmer Street site and provide advice on remediation along with rough order costings.

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3.0 Structural Review

3.1 General

All the buildings have undergone a degree of settlement and show some signs of distress which is detailed in the AECOM report Palmer Street Engineering & Environmental Investigation Factual Report (AECOM 2015a).

Typical minor distress includes loose bricks on corners, concrete spalling from foundation wall corners. More severe distress was observed as stepped cracking in brick walls and tilting of floors. Stairs and ramps to some buildings are no longer directly supported on the ground and have been propped with timber and bricks.

The following sections discuss the more severe distress related to floor level settlements and the condition of the existing foundations. Repairs are discussed in Section 5.0.

3.2 Floor Levels

The Ministry of Business, Innovation and Employment (MBIE) has produced guidelines for repairing buildings damaged in the Christchurch earthquakes. While these guidelines apply only to the Canterbury region, they provide a framework that can be used to assist in structural repairs in other regions. The buildings at Palmer Street are all classed as Type B, timber framed suspended timber floor structures with perimeter concrete foundations.

The MBIE indicators for floor repairs on Type B buildings and the classification of each building are:

Table 1 - Building deformations

Deformation	Repair	Building address
The slope of the floor between any two points >2m apart is <0.5% and the variation in level over the floor plan is <50mm.	No foundation re-level considered necessary	Hall, 188, 191, 226, 262, 280, 296
The variation in floor level is >50mm and <less than 100mm	Foundation re-level indicated	175, 184,210
The variation in floor level is >100mm over the floor plan or the floor has stretched by >20mm	Foundation rebuild indicated	152,158

3.3 Foundation Condition

3.3.1 Timber Piles

The timber piles exposed on the corner of No. 175 appear in good condition given their age and the existing plans note that they were to be constructed using treated timber, although a grade is not specified. A pile was partially exposed on the corner of No. 210, and was found to be rotten and soft. It was noted that in this location stormwater from the roof was discharging directly on the ground surface.

A new timber pile with an appropriate level of treatment would be expected to have a design life of 50 years. It is not known what level of treatment the rotten pile has but it may also be approaching the end of it's design life.

The only way that the pile conditions can be verified is to excavate adjacent to all the piles. This is not practical and would be limited by the depth of excavation.

3.3.2 Concrete Piles

Concrete piles were observed within the subfloor space of at least one building. These will be shallow and founded in the near surface soils. The concrete appeared in reasonable condition for the age of the piles.

3.3.3 Subfloor Framing

The subfloor framing on the buildings where the subfloor was inspected appears dry and in good condition.

3.4 Superstructure Condition

No major superstructure damages were observed during the walk-throughs. Closer inspections should be undertaken during the re-levelling and foundation replacements.

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4.0 Geotechnical Assessment

4.1 Introduction

The land and buildings at the Palmer Street site have undergone post construction settlement. The land adjacent to buildings has settled up to 250 mm assuming no re-medial landscaping has taken place. The floor levels indicate that the floors have undergone a degree of settlement less than the adjacent land.

This is likely due to the more heavily loaded perimeter foundations being supported on driven piles that presumably have been predrilled or driven through the fill so the buildings haven't responded to the settlement to the same degree. It is unknown if the piles were designed for construction to a target depth or if they were driven to achieve a set determined by a pile driving formula. The latter was common at the time of construction and is no longer recommended.

Negative skin friction on the piles would have developed as the fill settled. This would have increased the load on the piles and may be responsible for inducing settlement of the pile foundations.

To evaluate remedial options an understanding of the geotechnical constraints at the site is required.

4.2 Geological Setting

The township of Te Awamutu is located within the southern area of the Hamilton Lowlands on low rolling hills. The geological units that are associated with the rolling hills in Te Awamutu are the Walton Subgroup and the overlying Hamilton Ash.

The Hamilton Ash is a series of highly weathered, clay rich rhyolitic, tephras. The ashes were deposited between 80 and 380 thousand years ago. The ashes mantled the pre-existing landscape and can be up to 6 metres thick locally.

The geological map for the area (Edbrooke, 2005), indicates that the site is underlain Walton Subgroup.

The Walton Subgroup comprises the Puketoka and Karapiro Formations and dates from about 1 to 0.4 million years ago. These are variable alluvial deposits and ignimbrites that are typically highly weathered near the surface. Although the Walton Subgroup is typically not a surface deposit in the Hamilton Area it can be encountered in excavations on the rolling hill topography.

Historic aerial photographs presented in the Environmental Contamination Report Detailed Site Investigation (DSI) (AECOM, 2015b) indicate that the site was formally a gully with a swampy base. The uncontrolled fill was placed within the gully prior to the construction of dwellings.

4.3 Geotechnical Investigations

The following geotechnical investigations have been undertaken:-

- 2 Machine pits, 20 machine augers, 3 hand augers reported by G.A. Hughs and Associates Ltd, titled Geotechnical Investigations Palmer Street, Te Awamutu, reference 61994C / 1 – 26 and dated 20 May 2013.
- 5 Cone penetrometer tests, 4 boreholes, and 12 handaugers by AECOM as part of Palmer Street Engineering & Environmental Investigation Factual Report (AECOM 2015a).

The data collected from these investigations is presented in AECOM 2015a

4.4 Summary of Investigations

4.4.1 Boreholes and Handaugers

All investigations have found a shallow cover layer of sandy silt and silty sand overlying refuse. The cover layer varied in thickness from 0.3 to 1.2 m. The type of refuse encountered varied and included: glass bottles, ceramic plates, pieces of plastic and plastic wrapping, concrete, corrugated iron, wire, and shards of metal. The fill was found to be up to 6 m deep, however the typical depth was 2 to 3 m. A fill depth contour plan has been prepared from all the existing data and is presented in Appendix A.

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The natural soil underlying the fill varies and logs show, silt, silty clay, sandy silt and peat.

Groundwater varies between 2 and 4.5 m s depth below existing ground level.

4.4.2 CPT Interpretation

The CPT data was interpreted using the software CPTet-IT v.1.7.4.42 developed by Geologimiski. The ground conditions were found to be reasonably consistent between each CPT.

The soil behaviour types identified in the CPT plots are predominantly clay and silty clay to approximately 15 m with organic soil up to 0.5 m thick below the fill material.

The CPTs generally show medium dense to dense sand and silty sand underlying the clay soils.

The soils identified in the CPT investigation are generalised in Table 2.

Table 2 Summary of ground conditions.

Unit	Description	Depth to the top of layer (m)	Layer thickness (m)	Cone Resistance (MPa)
1	Fill	0	< 2.5 m at test locations	N/A
2	Organic soil	2	0.1 – 0.5	0.1
3	Clay/ silty clay	2.5	2.5	1 – 6
4	Organic soil	5	0.1 – 0.5	0.1 – 1
5	Clay/ silty clay	5.5	4.5 - 13	0.7 – 6
6	Sand/ silty sand	10 - 18	2 – 10	13 – 30

4.4.3 Discussion

The soil profiles encountered in the boreholes and CPTs are consistent with the geological setting. The organic soils and peat underlying the fill are typical of swampy gullies. The silty and clayey soils are typical for Hamilton Ash and the upper units of the Puketoka Formation. The sand encountered at depth is also typical for Puketoka Formation.

4.5 Geotechnical Issues

Based on the data collected above, the potential geotechnical issues for this site are:-

1. Fill settlement
2. Underlying soft natural soil settlement
3. Appropriate founding layers
4. Seismic behaviour of the soils.

4.6 Static Settlement

4.6.1 Introduction

Static settlement of land has potential to result in damage to buildings and services. If the settlement is uniform then there may be very little damage if at all. Differential settlement is when the ground surface settles at different rates and/or magnitudes. Differential settlement is typically responsible for observed and ground depressions. At this site settlement is complicated by the uncontrolled fill overlying natural soil, both of which are susceptible settlement.

4.6.2 Settlement of NaturalS

The natural soils below the fill include some soft clays and organic soils. They are susceptible to consolidation settlement when loaded.

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A preliminary assessment of soil settlement has been undertaken using CPeT-IT. The analysis estimates the soil settlement likely to occur if an additional metre of fill is placed over the site. The load adopted was 18kPa to represent a well compacted clay. The assessment considers both primary settlement and secondary (creep) settlement.

The results for primary settlement are presented in Appendix B and Table 3. The primary settlement induced by different fill depths can be estimated by factoring Table 3.

Table 3 – Settlement of natural soil.

CPT Test	Approximate primary settlement per metre of fill(mm)
CPT01	65
CPT02	50
CPT03	100
CPT04	60
CPT05	20

The settlement is typically occurring in layers 0.5 to 1.0 m thick. The main settlement prone zones, relative to ground level, are 2 to 3 m, 5 to 7 m and 17 to 19 m. The exception is CPT05 which shows near uniform settlement from 2.5 to 7.5 m depth.

The secondary settlement has been estimated over a 50 year period and the estimates range from 45 to 110mm. It is important to note that the secondary settlement estimates would occur independently of any load being applied to the ground surface, and are also area wide so would affect surrounding properties, roads and services also. Secondary settlement is normally not mitigated as part of residential building design as abrupt changes resulting in high differential settlement tend not to occur.

If new fill was placed over the site it would be important to undertake additional detailed assessment to evaluate the time for primary settlement to reach 90% consolidation which would inform if preloading was needed to accelerate the settlement prior to additional works being undertaken. Detailed assessment would also evaluate if settlement due to the new load was likely to affect adjacent structures and infrastructure.

4.6.3 Settlement of the Uncontrolled Fill

Settlement within the uncontrolled fill is mainly attributed to:

- physical and mechanical processes that include the reorientation of particles, movement of the fine materials into larger voids, and collapse of void spaces;
- chemical processes that include corrosion, combustion and oxidation;
- dissolution processes that consist of dissolving soluble substances by percolating liquids and then forming leachate; and
- biological decomposition of organics with time depending on humidity and the amount of organics present in the fill.

Significant settlement occurs during and shortly after placement of the uncontrolled fill due to physical and mechanical processes, which is often referred to as *primary settlement*. Substantial additional settlement occurs at a slower rate over an extended period of time (hundreds of years)due to chemical and biological processes, which is often referred to as *secondary settlement* (Sowers 1973).

Settlement at this site has been underway since its placement in the 1950's. Unless additional loading is placed on the fill it is expected that the fill is currently undergoing secondary settlement. Settlement of the uncontrolled fill at this site is less easily quantified. There are anecdotal reports that the uncontrolled fill material was burnt prior to burial with soil. This should have destroyed the majority of decomposable material and reduced the volume of fill and also its long term biodegrading settlement potential. The fill contains metal objects that will continue to degrade over time. Once weakened these items tend to crush and produce immediate larger settlements at that time. There are also likely to be void pockets below any large fill items. Water percolating

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through the fill can transport fine material into these voids or where there is an outlet remove them completely from the profile.

For any new development on the site, whether it is buildings, services or vehicle manoeuvring areas, will need to be engineered to accommodate expected settlements and to be relatively easily repaired.

If any new fill is placed over the site it should be monitored by survey to ensure that the settlement induced by the new load has largely taken place prior to finalising the shape and finishing the surface.

4.7 Seismic Behaviour of Soils

4.7.1 General

Soil liquefaction typically occurs in fine-grained, generally non-cohesive and low plasticity soils. The susceptibility of a site to soil liquefaction is a function of particle size distribution, groundwater level, and soil density. The cyclic ground motion induced by earthquakes can cause a build-up of excess pore pressure within the soil. If this excess pore pressure is great enough, liquefaction can occur which causes a loss of bearing strength. As this excess pore pressure dissipates following an earthquake, densification of the soil can occur which can impact on ground surface settlement and foundation capacity.

Strain softening can occur in clay like soils when they are subjected to seismic loading. This results in a loss of strength but does not contribute to ground surface settlement. It can however contribute to lateral displacements, and result in a loss of bearing capacity.

4.7.2 Seismic Loading

The site is located in an area that has moderate seismic hazard and associated risk. Seismic loading was determined using NZS 1170.5:2004 Structural Design Actions Part 5: Earthquake Actions – New Zealand and the NZTA Bridge Manual.

The seismic loadings in NZS1170.5 2004 were determined by GNS Science and are normalised to a 7.5 Mw earthquake. It is now generally accepted within the geotechnical industry that the 7.5 Mw earthquake is overly conservative for liquefaction assessments particularly in areas where that magnitude is not expected. NZS 1170.5 also states that it does not address slope stability and soil liquefaction. The Bridge Manual contains a seismic hazard model also prepared by GNS science that is not normalised to 7.5 Mw so that both the magnitude and PGA vary across the country reflecting the changes in the risk profile. This has also been prepared specifically for use with slope stability and liquefaction assessment. The Bridge Manual is now widely accepted over NZS 1170 for determining the seismic loadings for use in liquefaction assessments.

The key inputs for the assessment are listed below:

- Site subsoil soil classification:	Class D – Deep or soft soil site
- Structure importance level:	2
- Structure design life:	50 years
- Serviceability return period factor R_s (AEP 1/25)	0.25
- Ultimate return period factor R_u (AEP 1/500)	1.0
- Bridge Manual $C_{0,1000}$	0.35
- Bridge Manual effective magnitude	5.9
- Serviceability limit state (SLS) peak ground acceleration	0.06g
- Ultimate limit state (ULS) peak ground acceleration	0.22g

4.7.3 Evaluation

Liquefaction has been evaluated using the software CLiq v.17.7.6.34 produced by Geologimiski and the following user controlled settings were adopted.

- Liquefaction triggering: Idriss & Boulanger (2008)
- Fines according to Robertson and Wride 1998
- Settlements according to Zhang et al 2004

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- Groundwater at 1 depth
- Clay like behaviour was assessed

4.7.4 Results

The results of the liquefaction assessment are presented in Appendix A. The results indicate that there are no predicted soil liquefaction or strain softening effects in the SLS (AEP 1/25) earthquake. There is very low probability of soil liquefaction and strain softening in the ULS (AEP 1/500) event. The maximum predicted ground surface settlement in the ULS event is 20 mm. This level of settlement is not expected to have a detrimental effect on any structures and therefore mitigation of the site for liquefaction is therefore not required.

4.8 New Foundations

Due to the ongoing risk of large settlement of the uncontrolled fill material all new foundations whether required for repairs or additions should be supported on new piles. All pile designs will need to account for negative skin friction from fill settlement either by increasing design loads or providing a method of isolation to prevent frictional interaction in the fill.

Driven piles can be considered where there is room to drive piles without damaging existing buildings. Driven piles would need to be predrilled through the fill and designed using current soil resistance equations. For work adjacent to existing buildings bored piles, screw piles or grouted micro-piles will be necessary. All pile types will require some drilling and removal of spoil to an appropriate controlled waste site..

We have undertaken a preliminary analysis of the ultimate pile capacity to estimate the range in embedment pile lengths required across the site. The results are presented in Appendix C and also in Table 4 for indicative load cases of 20 and 40kN respectively.

During the detailed design the ultimate load would include the negative friction component.

Table 4 - Depth to achieve ultimate capacity (m)

	Depth to achieve ultimate capacity (m bgl)									
	CPT01		CPT02		CPT03		CPT04		CPT05	
	20kN	40kN	20kN	40kN	20kN	40kN	20kN	40kN	20kN	40kN
Driven timber (175 SED)	3	8	5.5	8.5	6	9.5	6	8.5	7.5	9
Bored pile (300mm)	2.5	3	3.5	6	4	6	4	6.5	4.5	8
Screw pile (400mm)	2.5	3	4.5	7	3	7	5	6.5	7	8
Micro-pile (70mm)	10.5	15.5	9.5	15	11	16	11	13	9.5	10.5

The results indicate that there is variation across the site for the founding depth necessary to achieve the loads. With such variation, it would be appropriate to take a reasonably conservative approach during design of piles. Depending on the scope works and the proximity to existing test data it may be cost effective to undertake supplementary CPT tests to ascertain if shallower pile foundations are appropriate.

Location specific design of piles should be undertaken at detailed design stage.

4.9 Pavements

New pavements for vehicles or foot traffic should be constructed using pavement technology that can be readily mitigated in the event that localised depressions develop which result in undesirable surface gradient's ponding or cracking.

Three pavement types are outlined below. The finished surface would be constructed on compacted granular base course. To help mitigate surface settlement geogrids can be used within the basecourse layers to help the pavement span small depressions.

Asphalt pavements are suitable and can be remediated by localised patching. Asphalt pavements will increase stormwater runoff and management of stormwater quantity and quality will be required.

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Interlocking pavement blocks are also suitable. Remediation would involve lifting the pavers in the affected area and increasing the thickness of the base course prior to re-laying the pavers. Use of pavers would also result in increased stormwater runoff and necessitate management.

An alternative to hard pavements is to use a reinforced turf or gravel solution. Proprietary plastic cell products laid on a prepared base can be infilled with gravel or with topsoil for grassing. Both surfaces prevent rutting and material loss. A gravel surface would require on going weed control. A grassed surface is maintained as lawn and will maintain the sites existing stormwater runoff characteristics.

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5.0 Structural Repairs of Existing Buildings

5.1 Foundation

The condition of timber piles is unable to be verified and presents an element of risk particularly given the age of the piles and as they approach the end of their design life. The most risk adverse approach would be to construct new foundations for all buildings. At the other end of the scale the risk could be accepted and repairs proceed.

AECOM recommends a compromise solution for buildings where no re-levelling or re-levelling is recommended in the following sections. For these buildings the piles should be accepted in their current state and buildings are periodically monitored every few years for changes in levels, or more frequently if deformation is reported by tenants. This could be achieved by establishing benchmarks on the exterior of the buildings for survey. If movement is noticed then additional investigation is undertaken and a remedial plan adopted. A well-managed approach such as this should enable issues to be identified prior to extensive damage occurring.

5.2 No Re-level Required

On the basis of the deformations in Table 1 no foundation re-level is considered necessary for 7 of the 12 buildings on the site. Minor distress such as loose brick work and concrete spalling on foundation walls is not structural and cosmetic repairs are appropriate.

This recommendation applies to buildings 188, 191, 226, 262, 280, and the Hall.

The western unit of building 296 was not accessible and based on the existing information no re-level is necessary; however this should be confirmed prior to any building upgrade.

5.3 Re-level Recommended

Re-levelling is required for buildings 175, 184, and 210. For these building the measured floor levels indicate settlement requiring remediation. AECOM recommends that floor joists are jacked and packed at the bearers and perimeter foundation to re-level the building to within a 20mm tolerance.

This process will require that the external cladding is removed and rebuilt. Damage may also occur to plaster board lining. Door or windows that have adjusted to the buildings settlement may require re-adjustment or replacement if sticking or jamming occurs as a result of the re-levelling.

5.4 Foundation Re-build Recommended

Buildings 152 and 158 have undergone significant settlement resulting in structural damage. Building 210 has undergone excessive settlement and has a rotten pile.

AECOM recommends that these three buildings are underpinned using one of the pile solutions discussed in Section 4.8.

This process will require that the external cladding is removed and rebuilt. Damage may also occur to plaster board lining. Door or windows that have adjusted to the buildings settlement may require re-adjustment or replacement if sticking or jamming occurs as a result of the re-levelling.

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6.0 Environmental Assessment

6.1 DSI Findings

Uncontrolled fill has historically been placed within the site. A gully that traversed in a south-west to north-east direction across the site was infilled prior to the construction of pensioner housing between the 1950s and 1970s.

Activities of potential concern include:

- Filling activities – a previous site investigation indicated that the majority of the site is underlain by uncontrolled fill material containing refuse.
- Potential asbestos containing materials (ACM) and/or lead based paint associated with historic building materials and structures.

Based on the above the Detailed Site Investigation (DSI) (AECOM, 2015b) focussed on the characterisation of soil, groundwater, soil leachates and uncontrolled fill gas.

6.1.1 Uncontrolled Fill Gas

The uncontrolled fill gas survey comprised a gas walkover survey and targeted spiking survey. The walkover survey focussed on the identification of potential areas of concern as well as potential migration pathways. Methane was not detected in the crawl space of houses, but was identified at low concentrations at two external locations.

The targeted gas spiking survey, undertaken at five locations across the site, recorded only low methane concentrations. The presence of damaged services present at various locations across the site does however provide a potential pathway for gas migration and accumulation. Although ongoing gas generation is expected to be limited, there is potential for historically generated gas to have accumulated within services.

6.1.2 Soil

The fill materials are separated from site users by cover materials (sandy silt, with thickness ranging between 0.3 and 1 m) which limit the potential for direct contact. However, soils used to cover the uncontrolled fill contain concentrations of trace elements, including cadmium, lead and zinc, elevated above the regional background. In the case of lead, concentrations have been identified in excess of the criteria for protection of human health at discrete locations; although this is considered to be indicative of the heterogeneous nature of the contaminant/soil conditions and is not considered to be reflective of the average conditions. There is also potential for polycyclic aromatic hydrocarbons (PAH) concentrations to exceed the adopted acceptance criteria from similarly discrete locations. Risk associated with the presence of such elevated concentrations is primarily related to direct soil ingestion and accumulation in produce, with subsequent produce ingestion. To a great extent such exposure is mitigated by the current land-use (low produce consumption and limited potential for long term exposure for children) and the limited extent of areas with elevated contaminant concentrations. However, it is conservatively considered that there is potential for exposure to contaminants via the soil/produce ingestion pathways.

6.1.3 Groundwater and Leachate

The groundwater and leachate investigation comprised the advancement of three groundwater monitoring wells and one leachate monitoring well. Three groundwater monitoring wells are located on the margins of the fill area and screened in natural ground beneath the uncontrolled fill. A fourth monitoring well, located centrally within the site in an area interpreted to be the former gully that traversed the site.

The findings of the DSI interpreted that groundwater flows is in a north-easterly direction towards the Mangaohoi Stream, and is inferred to be in close hydraulic connection with the uncontrolled fill. The interpreted groundwater flow plan is shown in Appendix A.

Contaminant concentrations identified in the uncontrolled fill leachate and the immediately down-gradient groundwater are low and generally within the water quality requirements for potable water. While the influence of leachate is apparent in groundwater immediately down-gradient of the uncontrolled fill, this influence is considered minor. Furthermore, significant attenuation is expected to mitigate potential risks to the receiving environment.

Overall, the leachate discharge at the site is also not expected to adversely influence groundwater as a resource, or pose a potential risk to human health where groundwater is used for potable water supply due to the following:

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- Water supplies in the vicinity of the site are reticulated, with the nearest bore located 380 m east (across-gradient) of the site.
- Shallow groundwater is not used as a viable potable supply in the area owing to the low potential yields and poor security to anthropogenic effects (shallow unconfined aquifer).

6.2 Proposed Mitigation Measures

Pending confirmation on the scope and design of the infrastructure changes/upgrades for the site, the following management and mitigation measures are recommended to manage and mitigate potential adverse human health and environmental effects associated with site. It is noted that these are specific to the current land-use. Where an alternate land-use is considered, such as general residential, the potential for increased exposure to contaminants should be considered and mitigation/management measures developed accordingly. The proposed mitigation measures include:

1) A site management plan should be developed for the site addressing potential risks associated with disturbance of the fill cover materials and growing of produce. As a minimum, the plan should include:
    a) The adoption of raised garden beds for residents seeking to grow produce. Raised garden beds should be lined with geotextile barrier (marker layer) and comprise at least 500 mm of topsoil. Soil materials imported to the site should meet Regional Background Ranges for contaminants.
    b) Management/mitigation procedures around gardening activities, such as shallow excavations for the planting/removal of trees. In such cases, adequate reinstatement of the cover materials is required, including appropriate compaction.
    c) Delegation of responsibilities regarding the implementation of the plan and ongoing maintenance of the fill cover.
    d) Incident reporting procedures in the event that disturbance works are required.
2) In the event that existing buildings at the site are required to be modified or demolished as part of infrastructure changes/upgrades for the site, it is recommended that a hazardous materials survey be completed prior to works commencement. The hazardous materials survey would seek to confirm the presence of ACM and/or leads based paint and provide recommendations with respect to the abatement of these materials.
3) In the event that new residential dwellings are proposed for development at the site, as a conservative measure, an impervious membrane should be installed beneath the footprint of each building to mitigate the potential risk of gas infiltration associated with the uncontrolled fill. Underground services installed in support of the new residential dwellings should allow for continued passive venting of uncontrolled fill associated gasses.
4) Where the existing topsoil is not being stripped the existing surface should be protected from damage and mixing due to construction traffic and general site works. A layer of bidim cloth with a temporary running course of rotten rock will suffice for this purpose. At the completion of works the cloth and rock can be removed and the site hydroseeded.
5) Potential human health and environmental effects associated with land disturbance activities i.e., topsoil stripping, re-contouring, building modification or demolition, should be managed by way of a remedial action plan (RAP). The RAP should be developed to support resource consent applications and be provided to contractors for implementation during works. The management plan will reflect resource consent requirements and controls regarding soil disturbance. It will likely include the following elements:
    a) Summary of known site contamination conditions.
    b) Summary of responsible parties.
    c) Site specific safety requirements including personal protective equipment (PPE) and personal headspace monitoring for uncontrolled fill gasses during intrusive works.
    d) Procedures for unexpected materials discovery, material disposal and importation.
    e) Operational site management procedures for stockpile management, dust, erosion and sediment control.

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f) Requirements for maintenance or reinstatement of the fill-surface separation materials.

g) Site validation and reporting requirements.

These above recommendations are generally consistent with accepted industry guidance and standards including:

- Centre for Advanced Engineering, 2000. Landfill Guidelines, Towards Sustainable Waste Management in New Zealand.
- Ministry for the Environment, 2001. A Guide to the Management of Closing and Closed Landfills in New Zealand.
- Australian New Zealand Standard, 2009. Explosive atmospheres – Classification of areas – Explosive gas atmospheres (AS/NZS 60079.10.1:2009).

6.3 Resource Consenting Requirements

6.3.1 Land Disturbance Works

Under the Resource Management Act (National Environmental Standard for Assessing and Managing Contaminants in Soil to Protect Human Health) Regulations 2011 (NES CS), the requirement to apply for consent is driven by the historical land use of the site or 'piece of land' and the proposed activity. The provisions of the NES CS apply to the site during future land disturbance activities associated with site redevelopment. The available site investigation data is considered sufficient to allow for development works at the site to be undertaken as a Restricted Discretionary Activity under the NES CS (Clause 10). This consent will be required from the Waipa District Council.

6.3.2 Long-term Passive Discharge Consent

The WRP contains specific policies and implementation methods to address the significant resource management issues for the region identified in the Waikato Regional Policy Statement (RPS) and Proposed RPS. Details specific to water resources and discharges are set out in Section 3 of the Plan, and Section 5 of the Plan provides specific requirements in relation to land and soil. While investigations indicate that the minor discharge from the site is not creating any adverse effects beyond the boundaries of the site, a resource consent authorising long-term passive discharge of leachate contaminants from the site (Rule 3.5.4.5) may still be required to authorise the situation. , .

Discussion with Waikato Regional Council (WRC) should be undertaken in the next phase of works to confirm their position on consenting requirements for the site.

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7.0 Underground Services

7.1 Assessment

Wastewater / Stormwater

Wastewater and stormwater pipelines in the site are serviceable but are generally in average to poor condition. Many of the observed displacements are minor. There are a small number of large displacements and sagged sections of pipeline holding water should be replaced soon.

Stormwater and wastewater lateral services are in worse condition overall, when compared to the larger diameter public mains running through the site.

The concrete stormwater mains are generally in good condition, barring several large displacements. Joint deflection is evident through displaced rubber rings and debris (bedding) in the pipeline. Some joints are showing signs of stress and damage probably caused by shear loading due to settlement. The earthenware wastewater mains are in similar condition to the stormwater mains.

If significant settlement occurs in the future, socket joints are likely to deteriorate further (cracking, spalling and displacement of rubber rings). Flush joints (wastewater) will continue to displace but may not damage the pipeline sections.

Joint and crack defects in wastewater can result in groundwater inflow or exfiltration from the pipeline. The instance of inflow is low in the CCTV record, so it is likely that wastewater is discharging to ground. The addition of wastewater or stormwater into the uncontrolled fill is not ideal because it increases the amount of leachate generated.

Water

The water services are in good overall condition and remain serviceable apart from minor backlog maintenance items. The replacement of copper pipe with flexible PE pipe, when required due to modification or leakage is an acceptable approach. Complete replacement in the near future is not deemed to be required.

7.2 Remaining Life and Remedial Options

7.2.1 Remaining life

Deflection and displacement appears to be the primary defect type. This is consistent with the nature of the site, having settled over a long period, with only minor differential settlement.

The amount of future settlement is difficult to determine. For that reason the remaining life of the overall wastewater and stormwater systems could range from 1-3 years at worst, up to about 10 years with backlog maintenance (i.e. jetting and targeted repairs). Concrete stormwater pipelines may have a longer remaining life, provided future settlement is limited.

7.2.2 Remedial Methods for Wastewater and Stormwater

Pipe bursting

Pipe bursting effective for small diameter unreinforced pipe. This may be viable for the lateral services at the site but is not recommended for the following reasons:

- Existing lateral services are typically shallow and easily accessed. There appears to be no significant constraints to excavation and replacement which is the usual reason for trenchless solutions.
- There is scope to improve the general alignment of services at the site, which could not be achieved by bursting on line. There are also a number of sharp bends which either requires a chamber to be installed, or open excavation to install bends.
- Existing stormwater laterals terminating in soak holes will need to be extended by open trenching.

Lining

Slip lining involves lining the existing pipe with a smaller diameter pipe. Cured in place lining involves lining the existing pipe with a thin structural liner which is cured in the pipe itself. Both methods reduce the capacity of the host pipe, with slip lining having the largest reduction.

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Slip lining or is not appropriate for small diameter lateral services because it limits capacity for flow and solids (wastewater). Cured in place lining is not normally cost effective for small diameter shallow pipelines. Therefore, lining of lateral services is not viable.

Slip lining or cured in place may be viable for larger diameter public mains in the site. Slip lining will result in a marked reduction in capacity. Flow assessment would be required to determine if a reduction is acceptable. Both methods will retain any low points which have developed in the sewer to date because the existing gradient is unchanged.

Excavate and replace

Excavate and replace is a viable method or replacement for all pipelines in the site. The key benefits of replacement are as follows:

- Pipelines can be re-graded, or alignments changed to maximise slope and minimise length which will lower the risk of future settlement effects.
- The pipelines can be replaced with a flexible material with watertight joints (e.g. welded polyethylene) to accommodate minor settlement and to minimise water infiltration or exfiltration.

Low pressure sewers and sealed stormwater

The installation of individual wastewater grinder pumps discharging off the site in small diameter flexible pipelines has been considered. Such a system provides resilience against settlement because it does not rely on gravity. On a per dwelling basis this type of solution could be more costly than pipeline replacement. However, one pump may be able to be used for several units which could make it cost effective.

This option could be combined with a shallow sealed stormwater system, which would also have some resilience to settlement if it is designed to surcharge.

The full benefit of this solution may only be realised if the site is anticipated to settle in the future. However this cannot be accurately predicted.

The main pipelines located through the site would still need rehabilitation or diversion as they receive discharges from other upstream properties.

7.3 Conclusion and Recommendation

Water services at the site are serviceable but require replacement in the near future. Replacement could be carried out on a case by case basis, or in full as part of major site redevelopment or rehabilitation.

Targeted repair of a number of large defects is required now. Notwithstanding that, the services may remain in place provided that periodic inspection and maintenance is carried out and replacement or rehabilitation is planned as future works.

7.3.1 Wastewater and Stormwater Services

Excavation and replacement of lateral service connections is recommended. The site is compact and service connections are relatively short. The services are also laid shallow and drop steeply into the main pipelines. Sufficient fall is available from the buildings to the main pipelines to lay new services at gradients that will be able to tolerate some settlement.

Main pipelines through the site could be rehabilitated by lining. However, targeted works are required to repair several large defects. These will require excavation, at which point it may be more cost effective to replace the entire service at an even grade, in a material which can tolerate minor settlement and remain watertight.

Because the site is on uncontrolled fill, soakage pits and unsealed pipelines may be adding to the leachate generated by the refuse within the fill. For this reason alone, replacement or rehabilitation may be required immediately.

If it is chosen to redevelop the site, it is the recommendation of this report that all pipelines are renewed. Further assessment of the most cost effective solution is required by carrying out preliminary design and cost estimates. The viable options are as follows:

1) Excavate and replace lateral services and reline main pipelines running through the site (subject to capacity assessment).

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2) Excavate and replace all pipelines and lateral services.

3) Service the site with small diameter low pressure sewers and sealed stormwater pipes (overall cost subject to the method of rehabilitation or diversion of main pipelines).

7.3.2 Water Services

Water services do not need specific actions unless leakage or failure occurs. If the site is significantly redeveloped or rehabilitated, all water services should be replaced at the same time.

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8.0 Summary and Recommendations

8.1 Summary

The structural, geotechnical and civil assessments have all identified issues with the existing buildings and infrastructure. While some buildings have experienced excessive settlement others have minor settlement and only require cosmetic repair. Only three buildings have been assessed as requiring significant underpinning works.

The underground services are in reasonable condition and remain serviceable, however repairs will be required in the near to medium future. Any new services should be future proofed for on-going settlement.

The technical assessments that have the most influence on the future use of the site are the environmental and planning assessments. The critical elements are:

- The likely need for resource consents from the Waikato Regional Council for passive ongoing discharge of leachate
- The need to mitigate potential worker and resident exposure to contaminants during any soil disturbance and/or produce ingestion.

Obtaining the consents is not anticipated to be problematic, however there will obviously be costs involved (potentially on an ongoing basis for monitoring/management) and there is the potential need to involve land outside the current study area.

The requirement for ongoing mitigation of potential exposure to contaminants by site users has implications for the use and management of the site. This is due to:

- The requirement for maintenance and responsibility for a site management plan, including enforcement of the mitigation measures detailed within the plan.
- Limitations on site use with regards to the growing of produce, with these to be limited to raised beds.
- Likely limitations on site use with regards to the potential for greater exposure where general residential conditions are considered (as opposed to the current land use). Detailed risk assessment of an alternate land-use scenario should be undertaken where a change in land-use is considered.

One option would be to permanently cease all residential occupation at the site and address the consenting and residual contaminant and refuse conditions. We understand that this is undesirable due to the site’s location and proximity to amenities used by the tenants.

Development of the site in one continuous operation would normally be preferred, however, it is understood there would be difficulties in finding suitable accommodation for all the current tenants at the site. Instead, progressive development of the site is considered more feasible. If the hall and building 226 are removed this would create a reasonably wide strip between Palmer Street and Roche Street and form stage one of the redevelopment. Stages 2 and 3 have potential to be to the north or south of this central strip depending on the overall plan for the site.

8.2 Recommendations

AECOM recommends that the following is undertaken:

- Development of master plan options for redevelopment including cost estimations for re-use of existing buildings and new buildings.
- Consideration on the contaminant mitigation measures (primarily raised beds and vapour barriers beneath residence) in each of the master plan options..
- Costings for each option.

In parallel with the above tasks it is recommended that discussions with the Waikato Regional Council and the Waipa District Council resource consents unit be held to confirm the consenting requirements (if any) for the site.

Once the preferred development option/approach has been determined, application(s) to the respective Councils to authorise the works and any ongoing discharges from the site should be made. These applications will need to include an Assessment of Environmental Effects as well as development of the proposed remedial action plan

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and site management plans to manage risks associated with residual contaminants during the works and in the long term respectively.

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9.0 Limitations

Recommendations and opinions contained in this report are based on site investigations and observations.

Inferences about ground conditions over the site are made on the basis of investigation results using geological principles and engineering judgement, however it is possible that ground conditions over the site may vary and therefore it is not possible to guarantee the continuity of the ground conditions away from test locations.

Inferences about building conditions are based on visual observation, floor level measurements and available plans. During any works to repair buildings it is possible that other items may be identified that require repair.

This report has been prepared for the particular project described in the brief to us, and no responsibility is accepted for the use of any part of this report in any other context or for any other purpose.

Information available at the time of writing was used for the preparation of this report. Any modification to the project will require a revision of this report.

Full limitations for the environmental assessment are given in Section 7.0 of the AECOM Environmental Contamination Report, dated 3 December 2015.

10.0 References

AECOM, Engineering & Environmental Investigation Factual Report (AECOM, 2015a). Ref: 60343891 prepared for Waipa District Council

AECOM, Environmental Contamination Report Detailed Site Investigation (DSI) (AECOM, 2015b). Ref: 60343891 prepared for Waipa District Council

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Sowers, G.F. 1973 Settlement of waste disposal fills. Proc. 3rd International Conference on Soil Mechanics and Foundation Engineering, Moscow, Vol.2, pp. 207-210

Taylor, M and Kim, N., 2009. Dealumination as a mechanism for increased acid recoverable aluminium in Waikato mineral soils. Australian Journal of Soil Research, 47, 828 - 838.

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Appendix A

Plans

Images taken from Google Earth

AECOM

PROJECT

Palmer Street Development: Stage 1

CLIENT

Waipa DISTRICT COUNCIL

Building Our Future Together

CONSULTANT

AECOM
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+64 7 834 8980 tel +64 7 834 8981 fax
www.aecom.com

REGISTRATION

FOR INFORMATION ONLY

PROJECT MANAGEMENT INITIALS

DESIGNER	CHECKED	APPROVED

ISSUE/REVISION

I/R	DATE	DESCRIPTION

KEY PLAN

Site boundary

PROJECT NUMBER

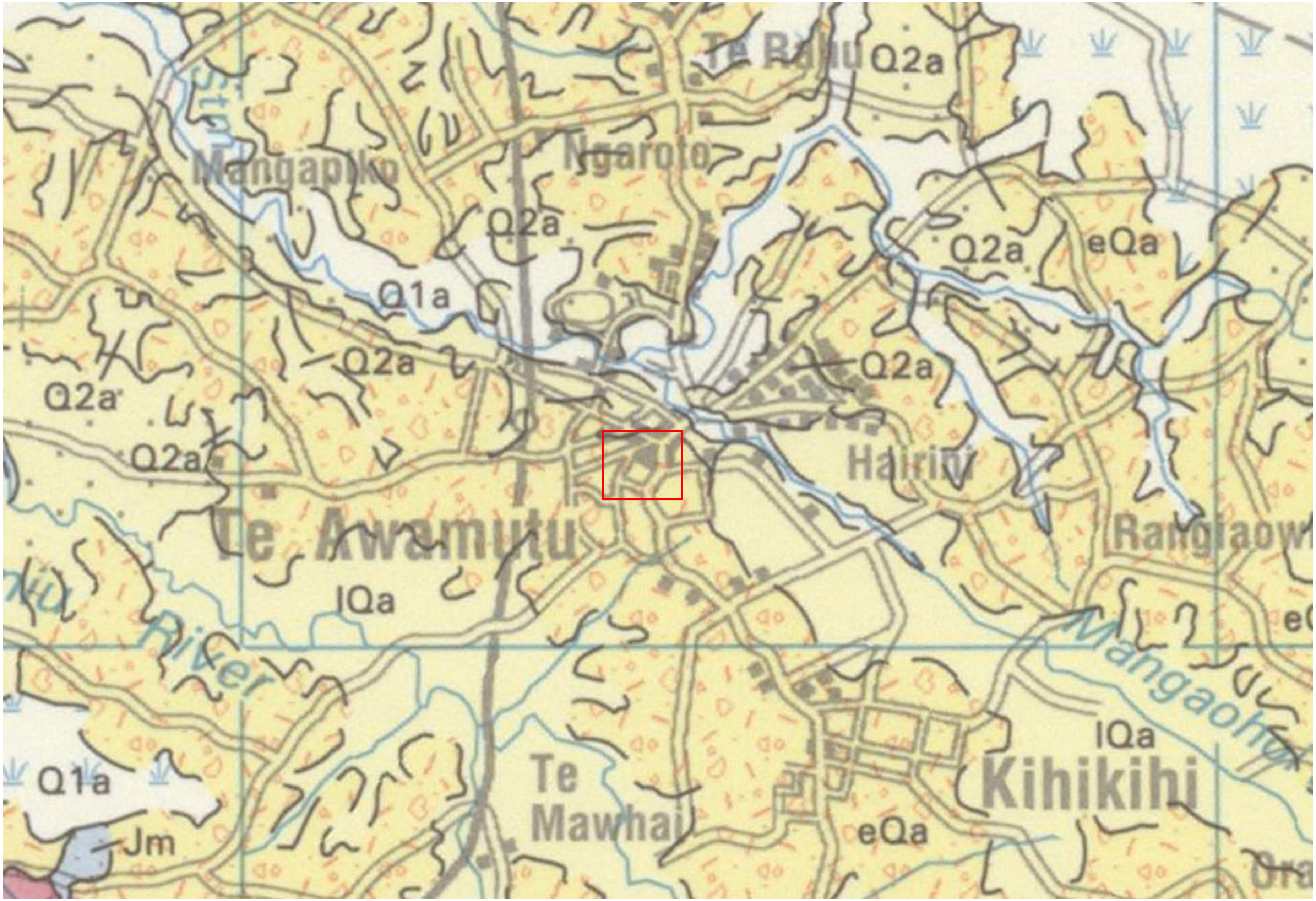
6043891

SHEET TITLE

Site Location Map

SHEET NUMBER

Sheet A1



eQa	Walton subgroup. Pumiceous alluvium and colluvium dominated by primary and reworked, non-welded ignimbrite.
lQa	Piako subgroup. Alluvial and colluvial pumiceous clay, sandy clay, silt and gravel with local muddy peat beds.

Edbrooke, S.W. (compiler) 2005. Geology of the Waikato Area.
Institute of Geological and Nuclear Sciences 1:250:0000 Geological map 4. 1 sheet + 68p.
Lower Hutt, New Zealand: Institute of Geological and Nuclear Sciences Limited.

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PROJECT MANAGEMENT INITIALS

DESIGNER	CHECKED	APPROVED

ISSUE/REVISION

I/R	DATE	DESCRIPTION

KEY PLAN
Site location

PROJECT NUMBER
60343891

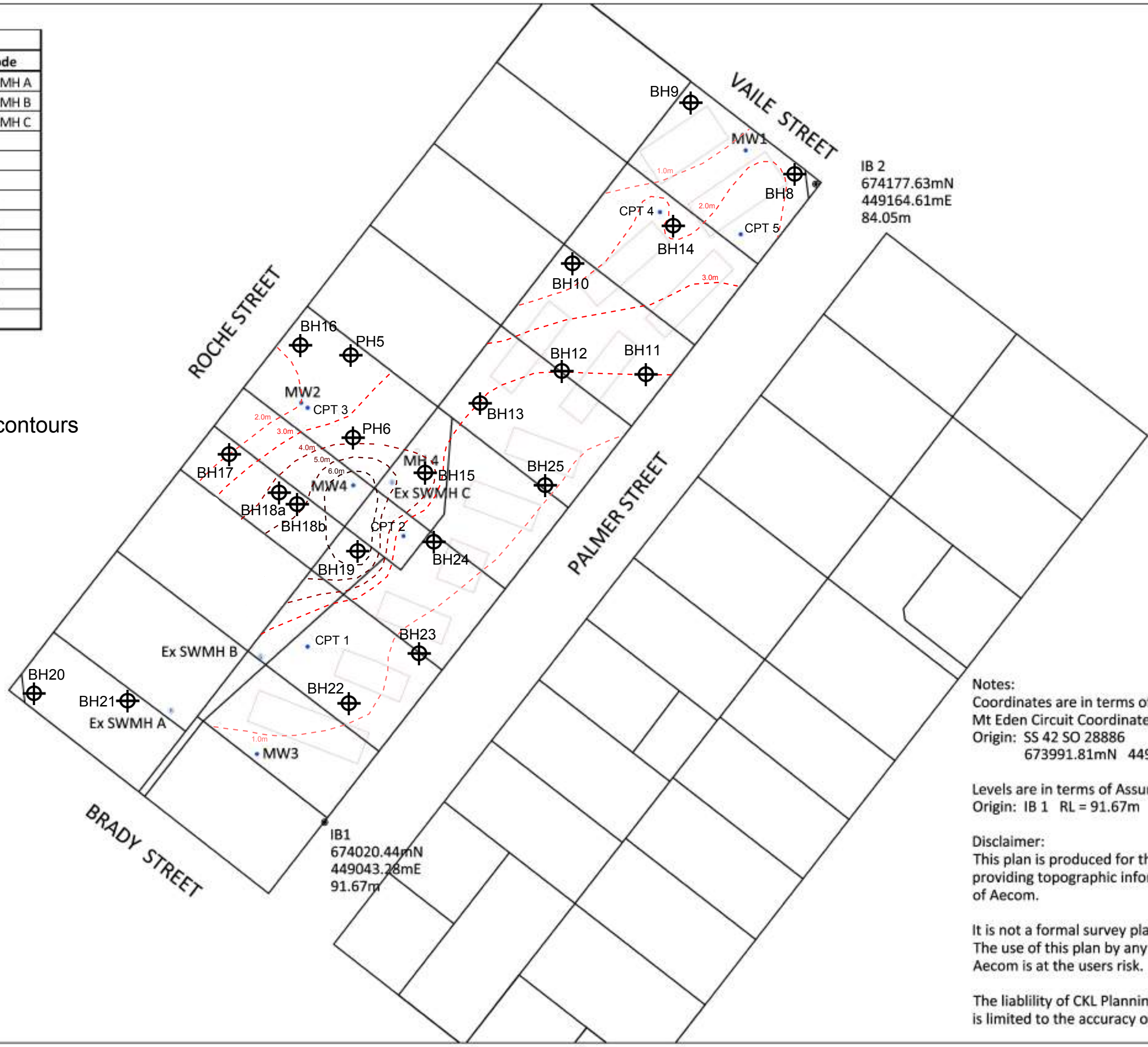
SHEET TITLE
Geological Map

SHEET NUMBER
Sheet A2

Schedule of Coordinates

X	Y	Z	Code
674049.20	449007.31	89.171	Ex SWMH A
674062.32	449029.13	88.713	Ex SWMH B
674104.91	449061.22	87.749	Ex SWMH C
674185.87	449147.49	85.334	MW1
674124.28	449039.04	88.766	MW2
674038.61	449028.26	89.221	MW3
674104.14	449051.74	88.05	MW4
674064.80	449040.59	88.503	CPT 1
674091.76	449063.99	87.57	CPT 2
674123.06	449040.60	88.769	CPT 3
674170.80	449126.58	85.515	CPT 4
674165.38	449146.29	84.997	CPT 5
674112.66	449067.38	87.097	MH 4

Interpreted fill depth contours



Notes:
Coordinates are in terms of Geodetic Datum 2000.
Mt Eden Circuit Coordinates.
Origin: SS 42 SO 28886
673991.81mN 449044.10mE

Levels are in terms of Assumed Datum.
Origin: IB 1 RL = 91.67m

Disclaimer:
This plan is produced for the sole purpose of providing topographic information for the use of Aecom.

It is not a formal survey plan of boundaries.
The use of this plan by any persons other than Aecom is at the users risk.

The liablility of CKL Planning | Surveying | Engineering is limited to the accuracy of the topographic data hereon.

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Palmer Street Development: Stage 1

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DESIGNER	CHECKED	APPROVED

ISSUE/REVISION

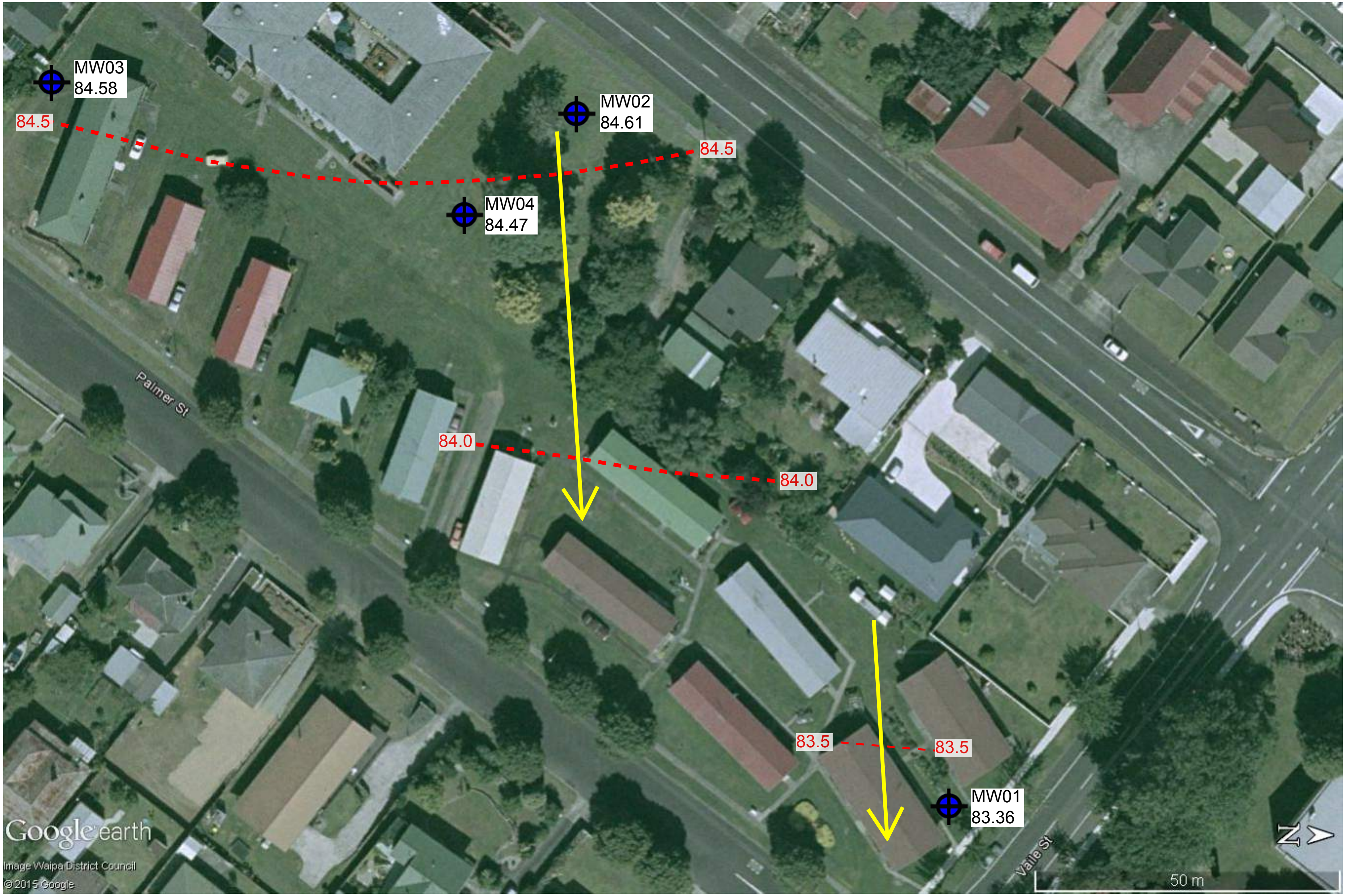
I/R	DATE	DESCRIPTION

KEY PLAN
- Water monitoring well/ CPT testing location
- Location of service strike
- GA & Hughs testing location (not surveyed)

PROJECT NUMBER
60343891

SHEET TITLE
Testing locations and fill depth

SHEET NUMBER
Sheet A3



84.0 - - - - - Piezometric contour

Groundwater monitoring well

Interpreted groundwater flow direction

MW01 83.36 Monitoring well reference & relative level of groundwater

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Palmer Street Development: Stage 1

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PROJECT MANAGEMENT INITIALS

DESIGNER	CHECKED	APPROVED

ISSUE/REVISION

I/R	DATE	DESCRIPTION

KEY PLAN

PROJECT NUMBER

6043891

SHEET TITLE

Interpreted Groundwater flow direction

SHEET NUMBER

Sheet A4

DRAFT

Appendix B

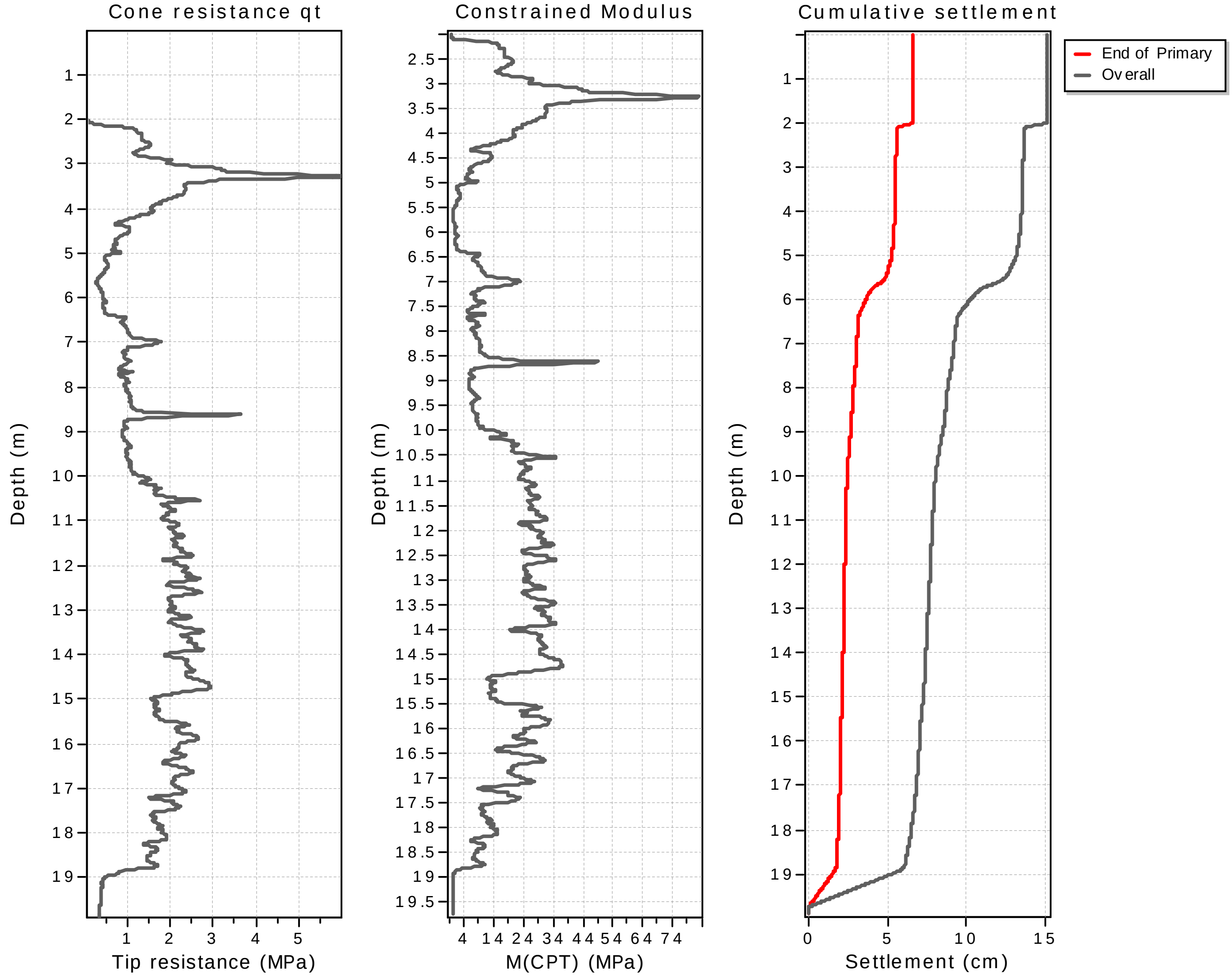
Static settlement

121 Rostrevor Street
Hamilton

Project: Palmer Street Development Stage 1
Location: Palmer Street

CPT: CPT-01
Total depth: 19.90 m, Date: 21/04/2015
Surface Elevation: 0.00 m
Coords: N -38.01327, E 175.32261
Cone Type: CPTu
Cone Operator: Ground Investigation

Settlements calculation according to theory of elasticity*



Caclulation properties

Footing type: Circular
Footing diameter: 50.00 (m)
L/B: 1.0
Footing pressure: 18.00 (kPa)
Embedment depth: 0.00 (m)
Footing is rigid: No
Remove excavation load: No
Apply 20% rule: No
Calculate secondary settlements: Yes
Time period for primary consolidation: 6 months
Time period for second. settlements: 600 months

* Primary settlements calculation is performed according to the following formula:

$$S = \sum \frac{\Delta\sigma_v}{M_{CPT}} \Delta z$$

* Secondary (creep) settlements calculation is performed according to the following formula:

$$S = C_a \cdot \Delta z \cdot \log(t)$$

:: Tabular results ::

Point No	Start depth (m)	End depth (m)	Thickness (m)	Relative depth (m)	Delta P (kPa)	$M_{(CPT)}$ (MPa)	Iz	Settlement (cm)	Second. settlement (cm)	Overall settlement (cm)
1981	19.81	19.82	0.01	19.82	13.69	0.00	0.76	0.000	0.000	0.000
1982	19.82	19.83	0.01	19.82	13.68	0.00	0.76	0.000	0.000	0.000
1983	19.83	19.84	0.01	19.84	13.68	0.00	0.76	0.000	0.000	0.000
1984	19.84	19.85	0.01	19.84	13.67	0.00	0.76	0.000	0.000	0.000
1985	19.85	19.86	0.01	19.86	13.67	0.00	0.76	0.000	0.000	0.000
1986	19.86	19.87	0.01	19.86	13.67	0.00	0.76	0.000	0.000	0.000
1987	19.87	19.88	0.01	19.88	13.66	0.00	0.76	0.000	0.000	0.000
1988	19.88	19.89	0.01	19.89	13.66	0.00	0.76	0.000	0.000	0.000
1989	19.89	19.90	0.01	19.89	13.65	0.00	0.76	0.000	0.000	0.000

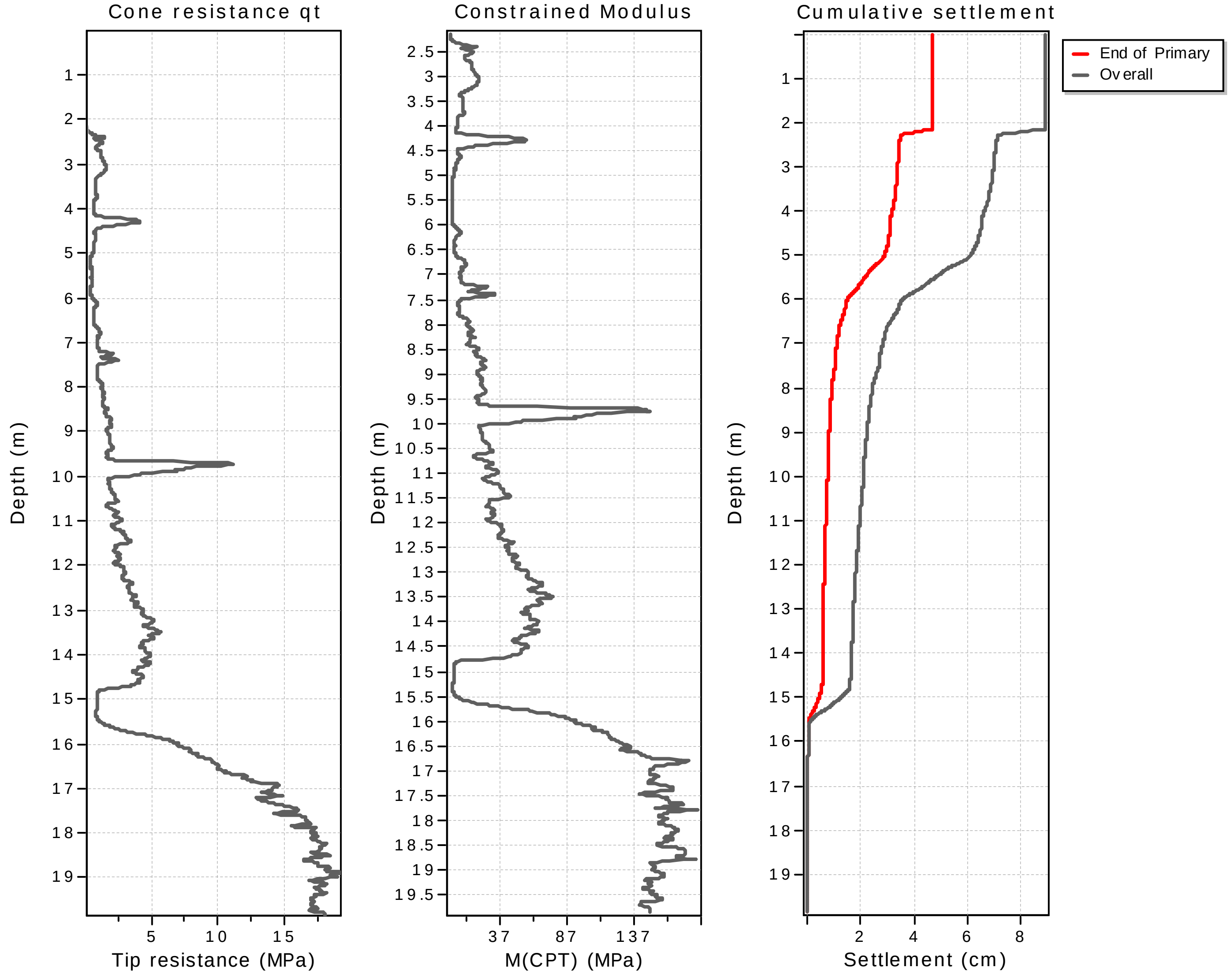
Total primary settlement: 6.59
Total secondary settlement: 8.53

Total calculated settlement: 15.11

Abbreviations

Start depth:	Start depth of soil layer (penetration depth measured from ground free surface)
End depth:	End depth of soil layer (penetration depth measured from ground free surface)
Thickness:	Thickness of soil layer
Relative depth:	Depth of calculation relative to footing
Iz:	Stress influence factor
Delta P:	Footing impossed stress:
Eff. stress:	Effective stress
$M_{(CPT)}$:	Constrained modulus from CPT
Settlement:	Primary settlement
Second. settlement:	Secondary settlemends due to creep

Settlements calculation according to theory of elasticity*



Caclulation properties

Footing type: Circular
Footing diameter: 50.00 (m)
L/B: 1.0
Footing pressure: 18.00 (kPa)
Embedment depth: 0.00 (m)
Footing is rigid: No
Remove excavation load: No
Apply 20% rule: No
Calculate secondary settlements: Yes
Time period for primary consolidation: 6 months
Time period for second. settlements: 600 months

* Primary settlements calculation is performed according to the following formula:

$$S = \sum \frac{\Delta\sigma_v}{M_{CPT}} \Delta z$$

* Secondary (creep) settlements calculation is performed according to the following formula:

$$S = C_a \cdot \Delta z \cdot \log(t)$$

:: Tabular results ::

Point No	Start depth (m)	End depth (m)	Thickness (m)	Relative depth (m)	Delta P (kPa)	$M_{(CPT)}$ (MPa)	Iz	Settlement (cm)	Second. settlement (cm)	Overall settlement (cm)
1981	19.81	19.82	0.01	19.82	13.69	148.85	0.76	0.000	0.000	0.000
1982	19.82	19.83	0.01	19.82	13.68	148.86	0.76	0.000	0.000	0.000
1983	19.83	19.84	0.01	19.84	13.68	148.86	0.76	0.000	0.000	0.000
1984	19.84	19.85	0.01	19.84	13.67	148.86	0.76	0.000	0.000	0.000

Total primary settlement: 4.71
Total secondary settlement: 4.21

Total calculated settlement: 8.92

Abbreviations

Start depth:	Start depth of soil layer (penetration depth measured from ground free surface)
End depth:	End depth of soil layer (penetration depth measured from ground free surface)
Thickness:	Thickness of soil layer
Relative depth:	Depth of calculation relative to footing
Iz:	Stress influence factor
Delta P:	Footing impossed stress:
Eff. stress:	Effective stress
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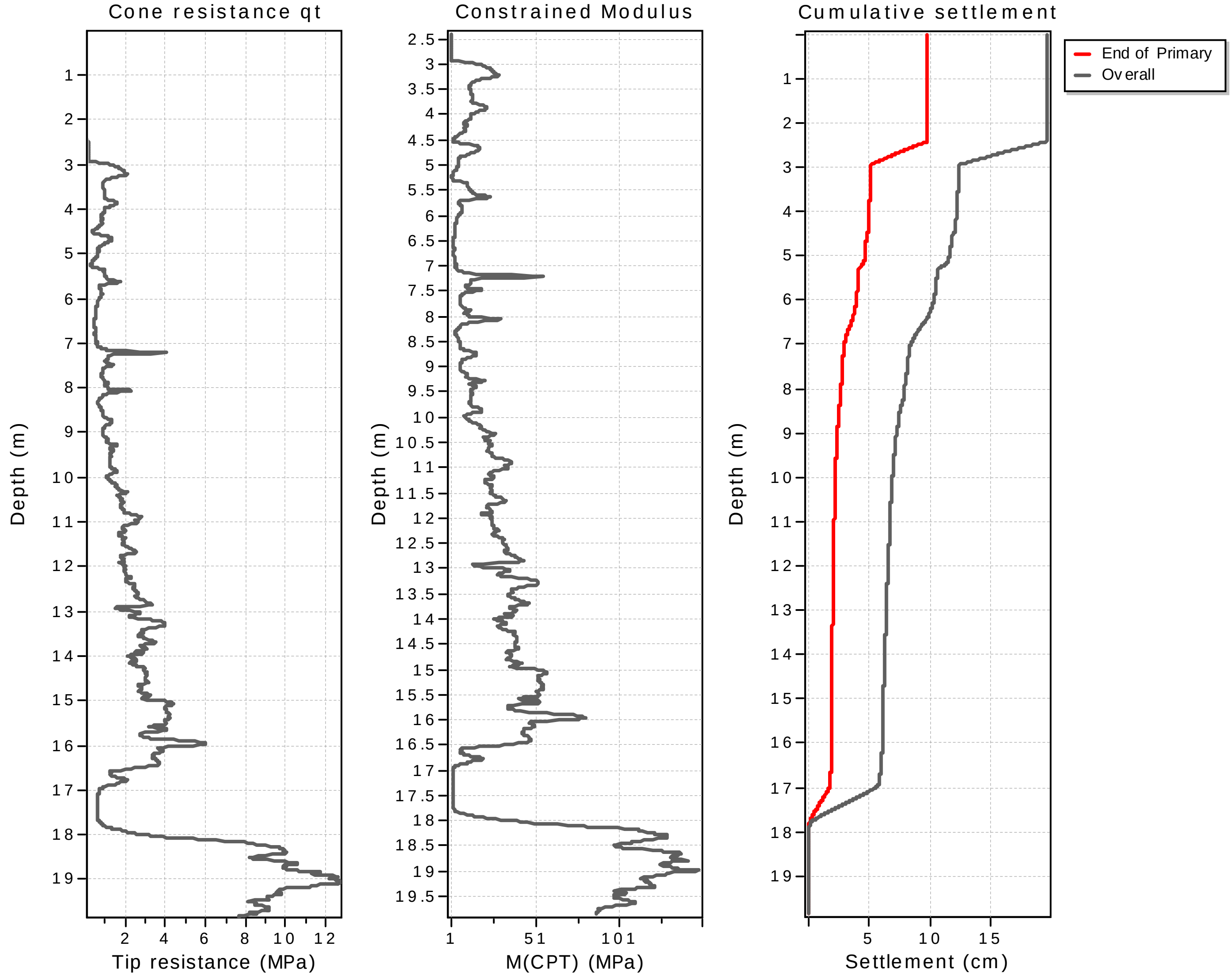
Settlement:	Primary settlement
Second. settlement:	Secondary settlemends due to creep

Settlements calculation according to theory of elasticity*



Caclulation properties

Footing type: Circular
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$$S = C_a \cdot \Delta z \cdot \log(t)$$

:: Tabular results ::

Point No	Start depth (m)	End depth (m)	Thickness (m)	Relative depth (m)	Delta P (kPa)	$M_{(CPT)}$ (MPa)	Iz	Settlement (cm)	Second. settlement (cm)	Overall settlement (cm)
1981	19.81	19.82	0.01	19.82	13.69	87.34	0.76	0.000	0.000	0.000
1982	19.82	19.83	0.01	19.82	13.68	87.27	0.76	0.000	0.000	0.000
1983	19.83	19.84	0.01	19.84	13.68	87.26	0.76	0.000	0.000	0.000
1984	19.84	19.85	0.01	19.84	13.67	87.25	0.76	0.000	0.000	0.000

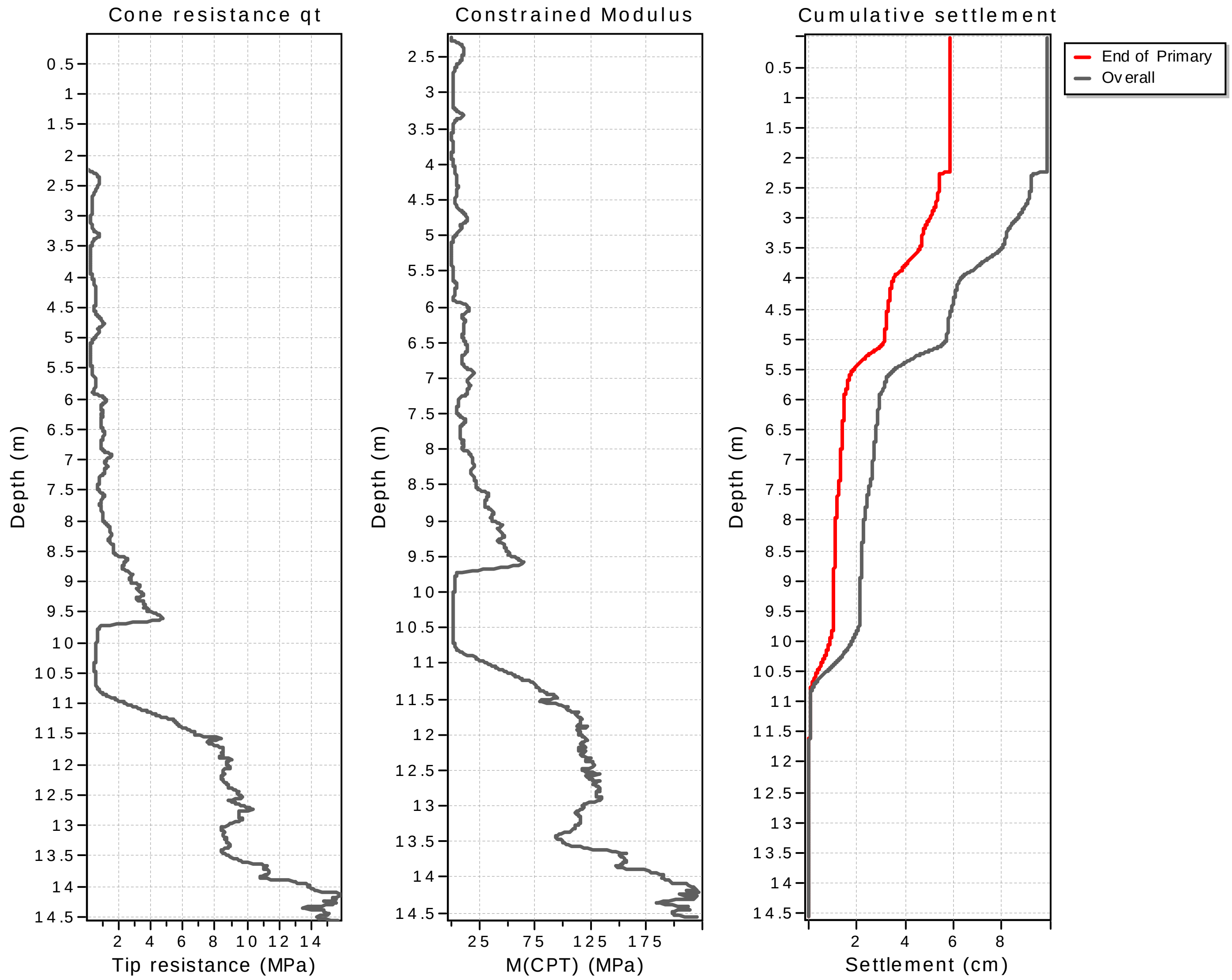
Total primary settlement: 9.78
Total secondary settlement: 9.83

Total calculated settlement: 19.61

Abbreviations

Start depth:	Start depth of soil layer (penetration depth measured from ground free surface)
End depth:	End depth of soil layer (penetration depth measured from ground free surface)
Thickness:	Thickness of soil layer
Relative depth:	Depth of calculation relative to footing
Iz:	Stress influence factor
Delta P:	Footing impossed stress:
Eff. stress:	Effective stress
$M_{(CPT)}$:	Constrained modulus from CPT
Settlement:	Primary settlement
Second. settlement:	Secondary settlemends due to creep

Settlements calculation according to theory of elasticity*



Caclulation properties

Footing type: Circular
Footing diameter: 50.00 (m)
L/B: 1.0
Footing pressure: 18.00 (kPa)
Embedment depth: 0.00 (m)
Footing is rigid: No
Remove excavation load: No
Apply 20% rule: No
Calculate secondary settlements: Yes
Time period for primary consolidation: 6 months
Time period for second. settlements: 600 months

* Primary settlements calculation is performed according to the following formula:

$$S = \sum \frac{\Delta\sigma_v}{M_{CPT}} \Delta z$$

* Secondary (creep) settlements calculation is performed according to the following formula:

$$S = C_a \cdot \Delta z \cdot \log(t)$$

:: Tabular results ::

Point No	Start depth (m)	End depth (m)	Thickness (m)	Relative depth (m)	Delta P (kPa)	$M_{(CPT)}$ (MPa)	Iz	Settlement (cm)	Second. settlement (cm)	Overall settlement (cm)
1441	14.41	14.42	0.01	14.41	15.76	203.36	0.88	0.000	0.000	0.000
1442	14.42	14.43	0.01	14.43	15.75	211.56	0.88	0.000	0.000	0.000
1443	14.43	14.44	0.01	14.44	15.75	208.66	0.87	0.000	0.000	0.000
1444	14.44	14.45	0.01	14.45	15.75	209.71	0.87	0.000	0.000	0.000
1445	14.45	14.46	0.01	14.46	15.74	213.87	0.87	0.000	0.000	0.000
1446	14.46	14.47	0.01	14.46	15.74	205.56	0.87	0.000	0.000	0.000
1447	14.47	14.48	0.01	14.47	15.74	202.54	0.87	0.000	0.000	0.000
1448	14.48	14.49	0.01	14.48	15.73	199.36	0.87	0.000	0.000	0.000
1449	14.49	14.50	0.01	14.49	15.73	197.33	0.87	0.000	0.000	0.000
1450	14.50	14.51	0.01	14.51	15.72	197.32	0.87	0.000	0.000	0.000
1451	14.51	14.52	0.01	14.52	15.72	198.57	0.87	0.000	0.000	0.000
1452	14.52	14.53	0.01	14.53	15.72	199.12	0.87	0.000	0.000	0.000
1453	14.53	14.54	0.01	14.54	15.71	199.56	0.87	0.000	0.000	0.000
1454	14.54	14.55	0.01	14.54	15.71	204.91	0.87	0.000	0.000	0.000
1455	14.55	14.56	0.01	14.55	15.71	209.82	0.87	0.000	0.000	0.000

Total primary settlement: 5.85
Total secondary settlement: 4.02

Total calculated settlement: 9.87

Abbreviations

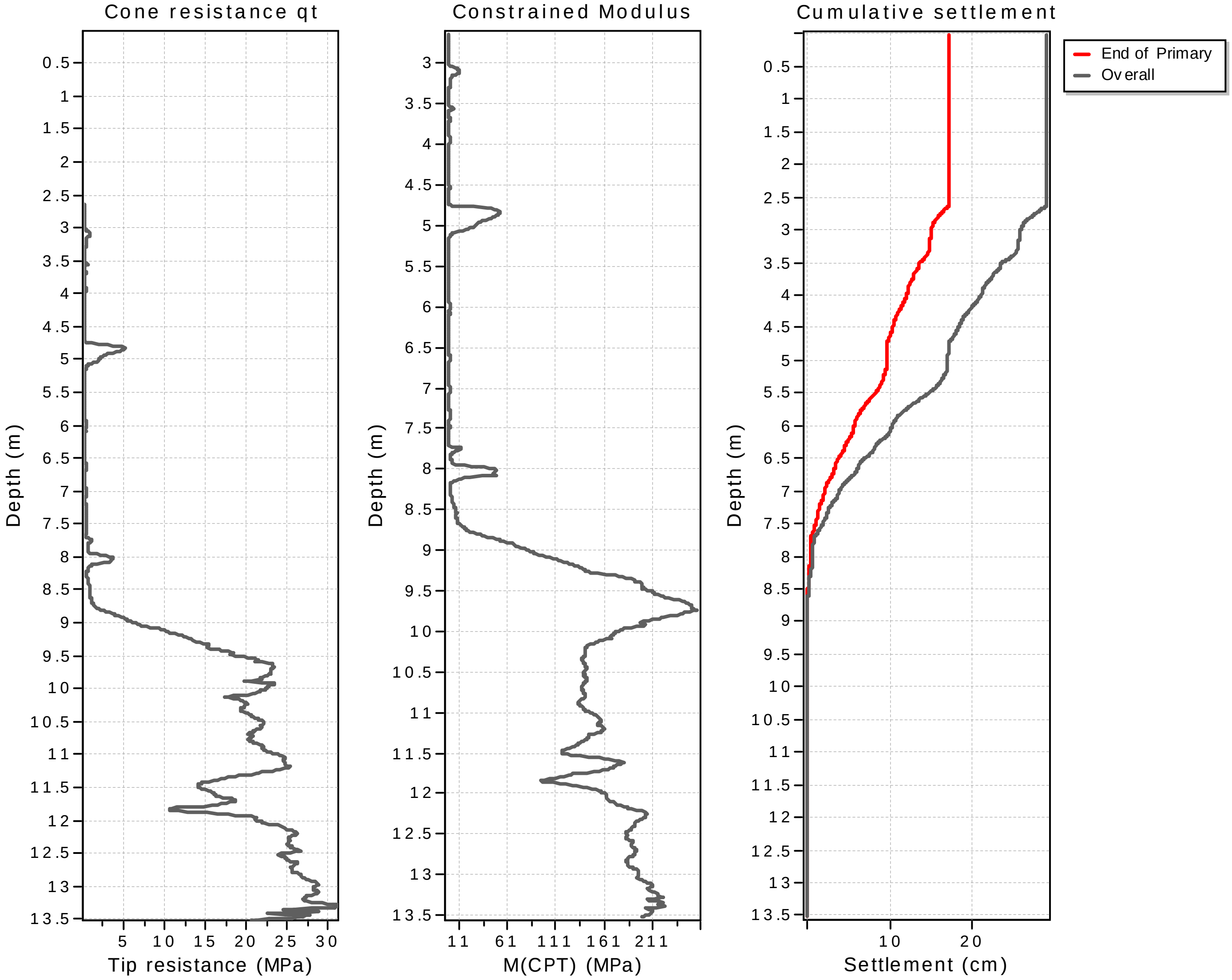
Start depth:	Start depth of soil layer (penetration depth measured from ground free surface)
End depth:	End depth of soil layer (penetration depth measured from ground free surface)
Thickness:	Thickness of soil layer
Relative depth:	Depth of calculation relative to footing
Iz:	Stress influence factor
Delta P:	Footing impossed stress:
Eff. stress:	Effective stress
$M_{(CPT)}$:	Constrained modulus from CPT
Settlement:	Primary settlement
Second. settlement:	Secondary settlemends due to creep

121 Rostrevor Street
Hamilton

CPT: CPT-05
Total depth: 13.52 m, Date: 20/04/2015
Surface Elevation: 0.00 m
Coords: -38.012290, 175.323870
Cone Type: CPTu
Cone Operator: Ground Investigation

Project: Palmer Street Development Stage 1
Location: Palmer Street

Settlements calculation according to theory of elasticity*



Caclulation properties

Footing type: Circular
Footing diameter: 50.00 (m)
L/B: 1.0
Footing pressure: 18.00 (kPa)
Embedment depth: 0.00 (m)
Footing is rigid: No
Remove excavation load: No
Apply 20% rule: No
Calculate secondary settlements: Yes
Time period for primary consolidation: 6 months
Time period for second. settlements: 600 months

* Primary settlements calculation is performed according to the following formula:

$$S = \sum \frac{\Delta\sigma_v}{M_{CPT}} \Delta z$$

* Secondary (creep) settlements calculation is performed according to the following formula:

$$S = C_a \cdot \Delta z \cdot \log(t)$$

:: Tabular results ::

Point No	Start depth (m)	End depth (m)	Thickness (m)	Relative depth (m)	Delta P (kPa)	$M_{(CPT)}$ (MPa)	Iz	Settlement (cm)	Second. settlement (cm)	Overall settlement (cm)
1351	13.51	13.52	0.01	13.52	16.06	201.14	0.89	0.000	0.000	0.000

Total primary settlement: 17.01
Total secondary settlement: 11.88

Total calculated settlement: 28.89

Abbreviations

Start depth:	Start depth of soil layer (penetration depth measured from ground free surface)
End depth:	End depth of soil layer (penetration depth measured from ground free surface)
Thickness:	Thickness of soil layer
Relative depth:	Depth of calculation relative to footing
Iz:	Stress influence factor
Delta P:	Footing impossed stress:
Eff. stress:	Effective stress
$M_{(CPT)}$:	Constrained modulus from CPT
Settlement:	Primary settlement
Second. settlement:	Secondary settlemends due to creep

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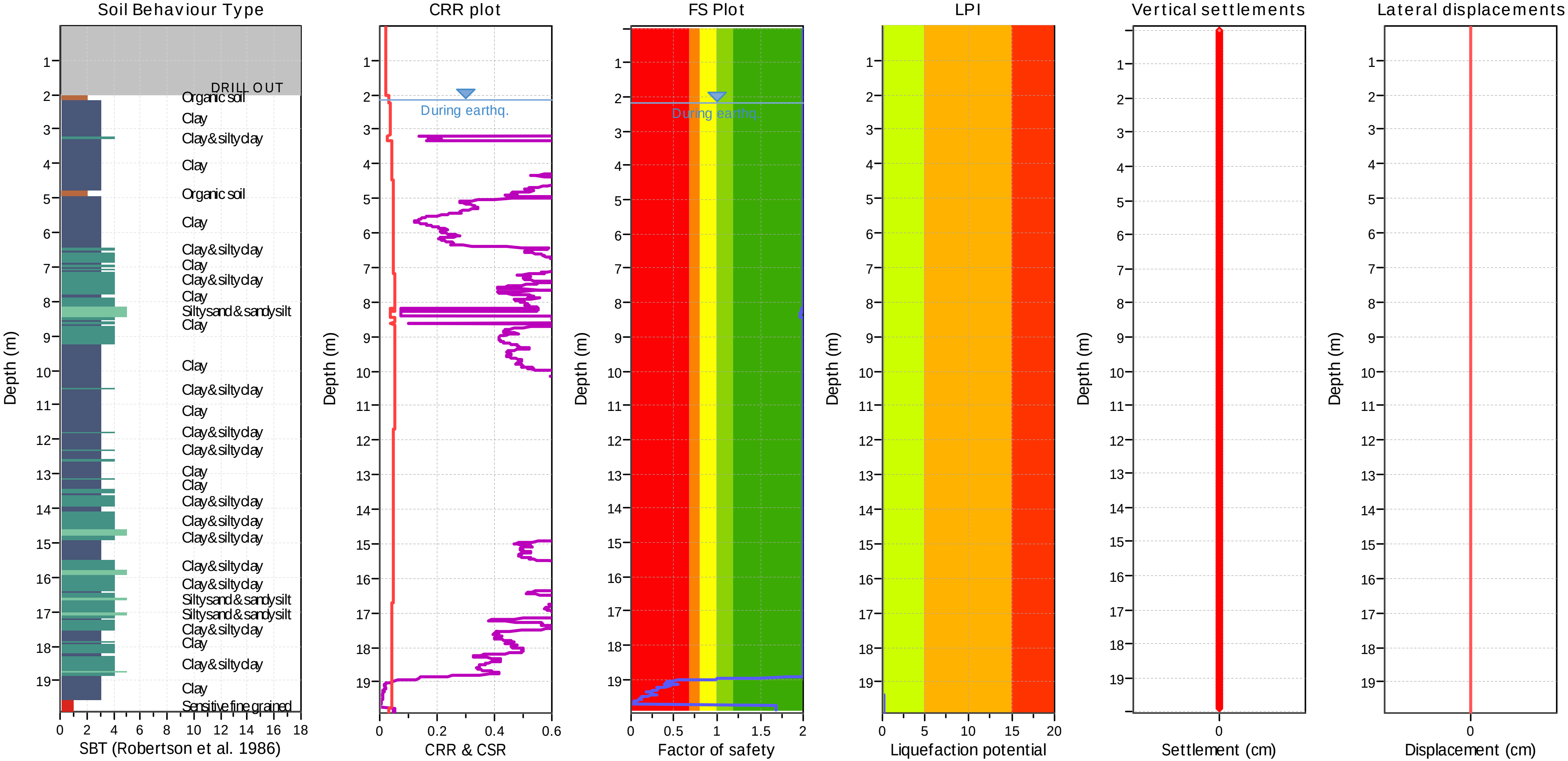
Appendix C

Seismic behaviour of soil

121 Rostrevor Street
Hamilton

Project: Palmer Street Development Stage 1
Location: Palmer Street

CPT: CPT-01 SLS
Total depth: 19.90 m



Analysis method:	I&B (2008)	G.W.T. (in-situ):	2.15 m	Use fill:	No	Clay like behavior applied:	Sand & Clay
Fines correction method:	R&W (1998)	G.W.T. (earthq.):	2.15 m	Fill height:	N/A	Limit depth applied:	No
Points to test:	Based on Ic value	Average results interval:	3	Fill weight:	N/A	Limit depth:	N/A
Earthquake magnitude M_w:	5.90	Ic cut-off value:	2.60	Trans. detect. applied:	Yes	MSF method:	Method based
Peak ground acceleration:	0.06	Unit weight calculation:	Based on SBT	K_σ applied:	Yes		

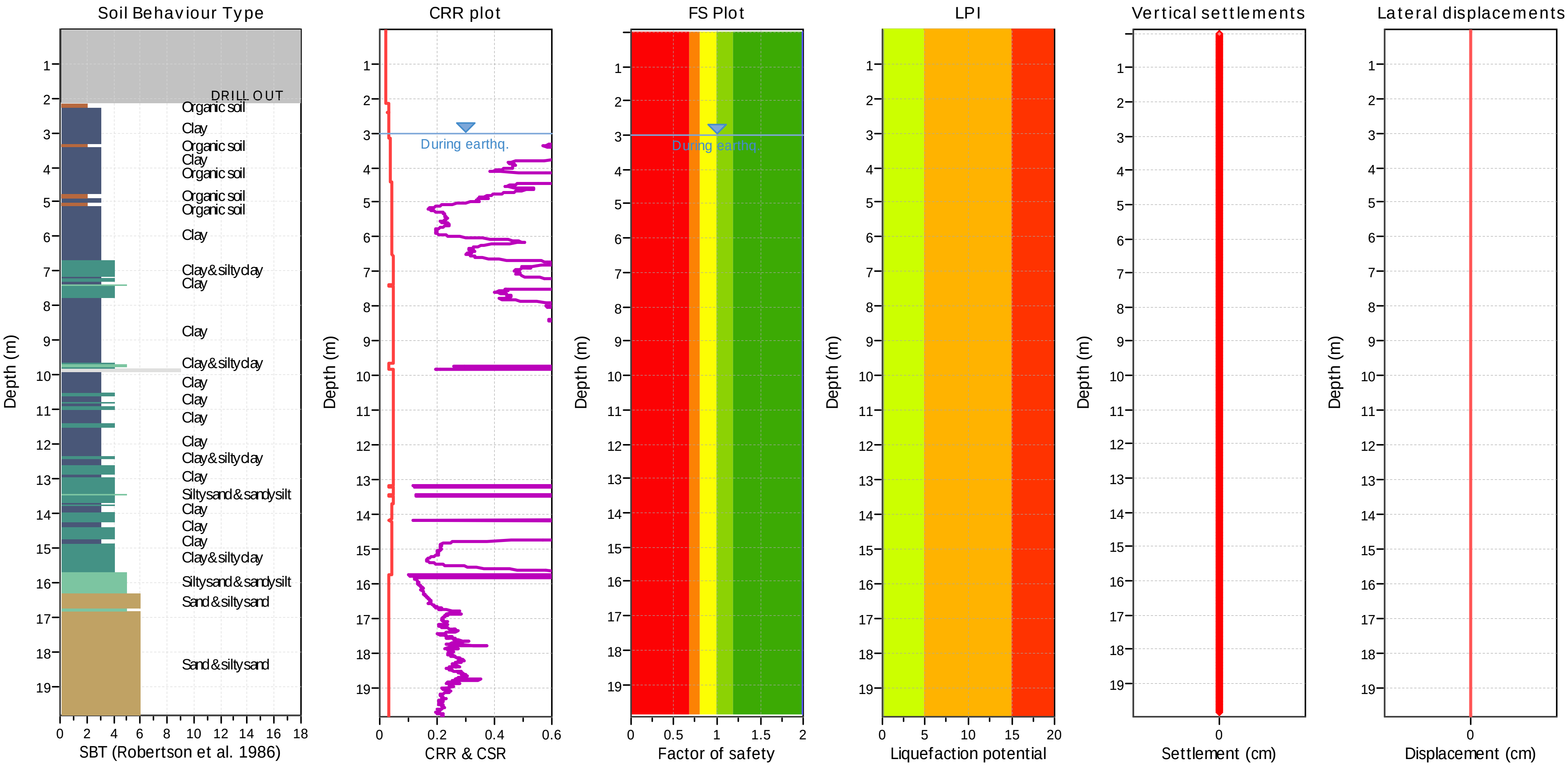
121 Rostrevor Street
Hamilton

Project: Palmer Street Development Stage 1

Location: Palmer Street

CPT: CPT-02 SLS

Total depth: 19.85 m

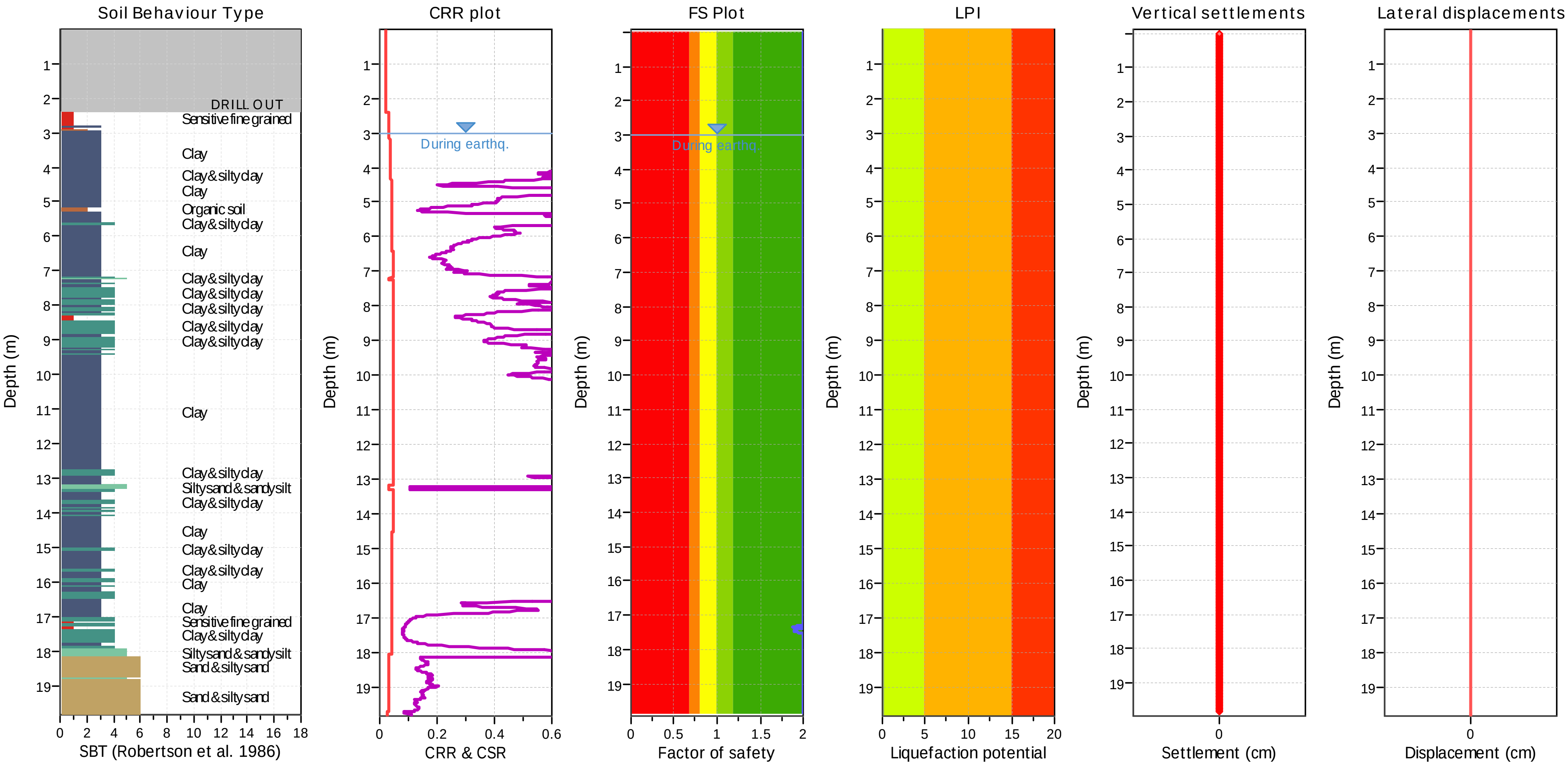


Analysis method:	I&B (2008)	G.W.T. (in-situ):	3.00 m	Use fill:	No	Clay like behavior applied:	Sand & Clay
Fines correction method:	R&W (1998)	G.W.T. (earthq.):	3.00 m	Fill height:	N/A	Limit depth applied:	No
Points to test:	Based on Ic value	Average results interval:	3	Fill weight:	N/A	Limit depth:	N/A
Earthquake magnitude M_w:	5.90	Ic cut-off value:	2.60	Trans. detect. applied:	Yes	MSF method:	Method based
Peak ground acceleration:	0.06	Unit weight calculation:	Based on SBT	K_σ applied:	Yes		

121 Rostrevor Street
Hamilton

Project: Palmer Street Development Stage 1
Location: Palmer Street

CPT: CPT-03 SLS
Total depth: 19.85 m

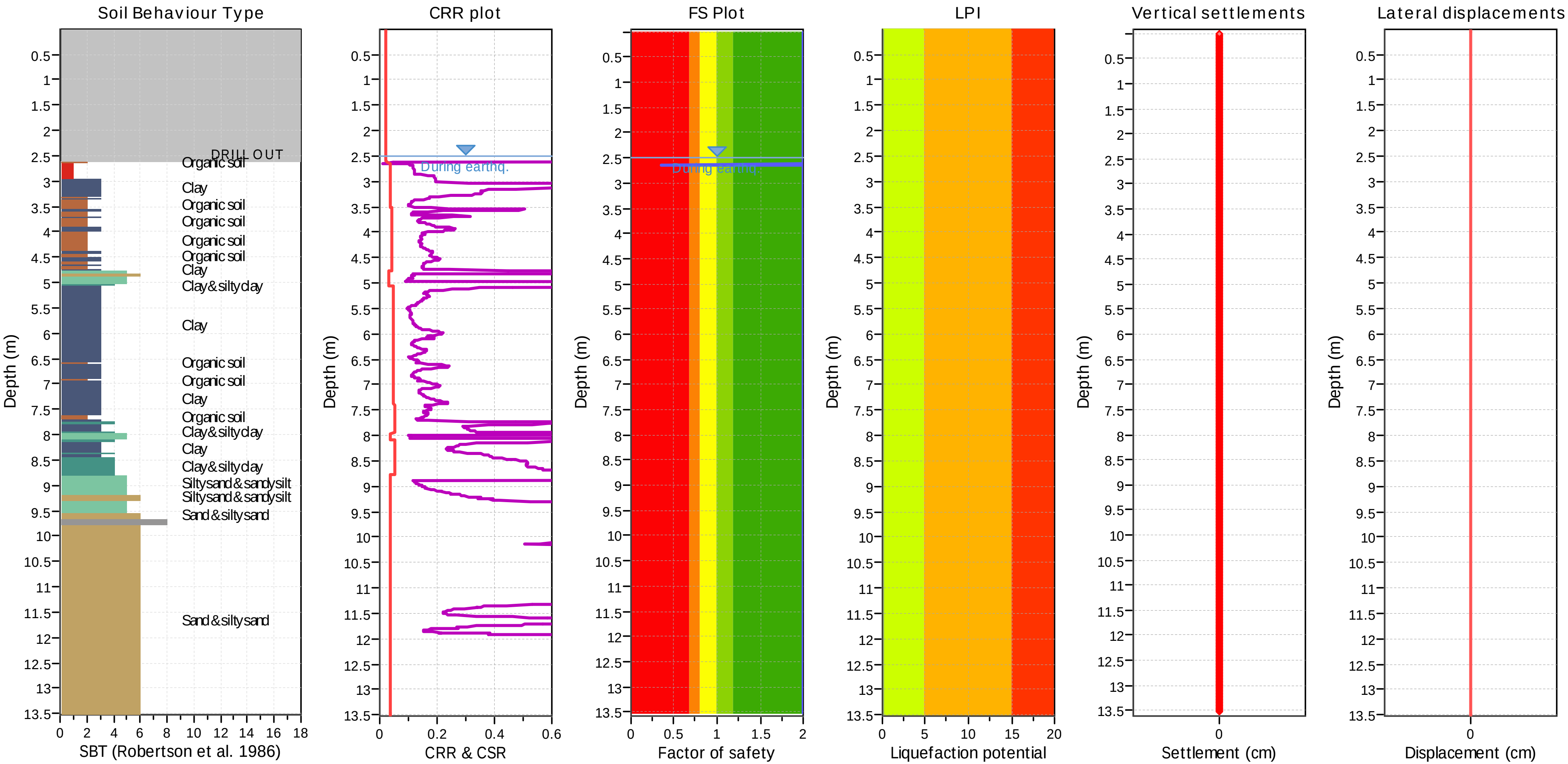


Analysis method:	I&B (2008)	G.W.T. (in-situ):	3.00 m	Use fill:	No	Clay like behavior applied:	Sand & Clay
Fines correction method:	R&W (1998)	G.W.T. (earthq.):	3.00 m	Fill height:	N/A	Limit depth applied:	No
Points to test:	Based on Ic value	Average results interval:	3	Fill weight:	N/A	Limit depth:	N/A
Earthquake magnitude M_w:	5.90	Ic cut-off value:	2.60	Trans. detect. applied:	Yes	MSF method:	Method based
Peak ground acceleration:	0.06	Unit weight calculation:	Based on SBT	K_σ applied:	Yes		

121 Rostrevor Street
Hamilton

Project: Palmer Street Development Stage 1
Location: Palmer Street

CPT: CPT-05 SLS
Total depth: 13.52 m

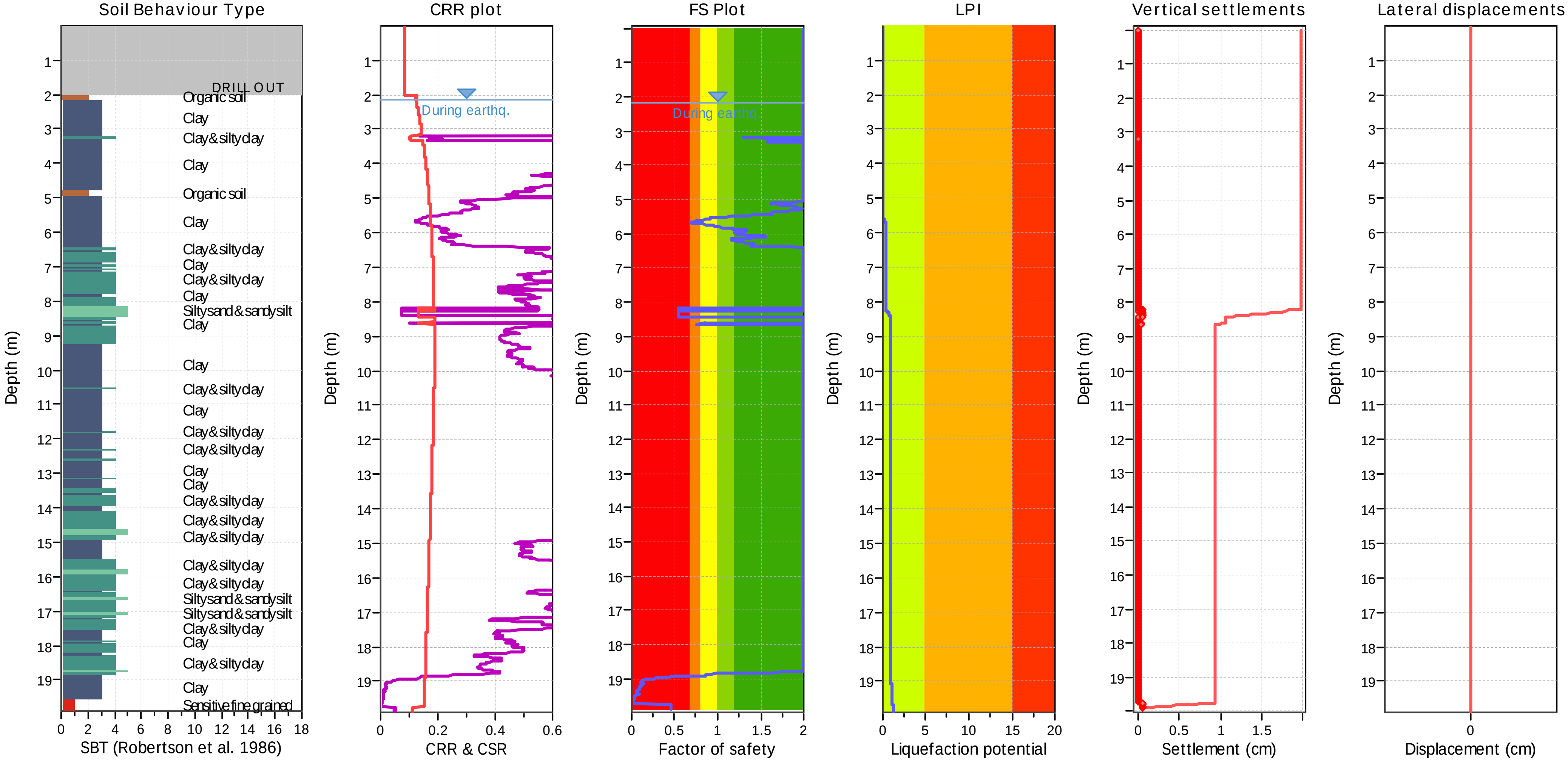


Analysis method:	I&B (2008)	G.W.T. (in-situ):	2.50 m	Use fill:	No	Clay like behavior applied:	Sand & Clay
Fines correction method:	R&W (1998)	G.W.T. (earthq.):	2.50 m	Fill height:	N/A	Limit depth applied:	No
Points to test:	Based on Ic value	Average results interval:	3	Fill weight:	N/A	Limit depth:	N/A
Earthquake magnitude M_w:	5.90	Ic cut-off value:	2.60	Trans. detect. applied:	Yes	MSF method:	Method based
Peak ground acceleration:	0.06	Unit weight calculation:	Based on SBT	K_σ applied:	Yes		

121 Rostrevor Street
Hamilton

Project: Palmer Street Development Stage 1
Location: Palmer Street

CPT: CPT-01 ULS
Total depth: 19.90 m

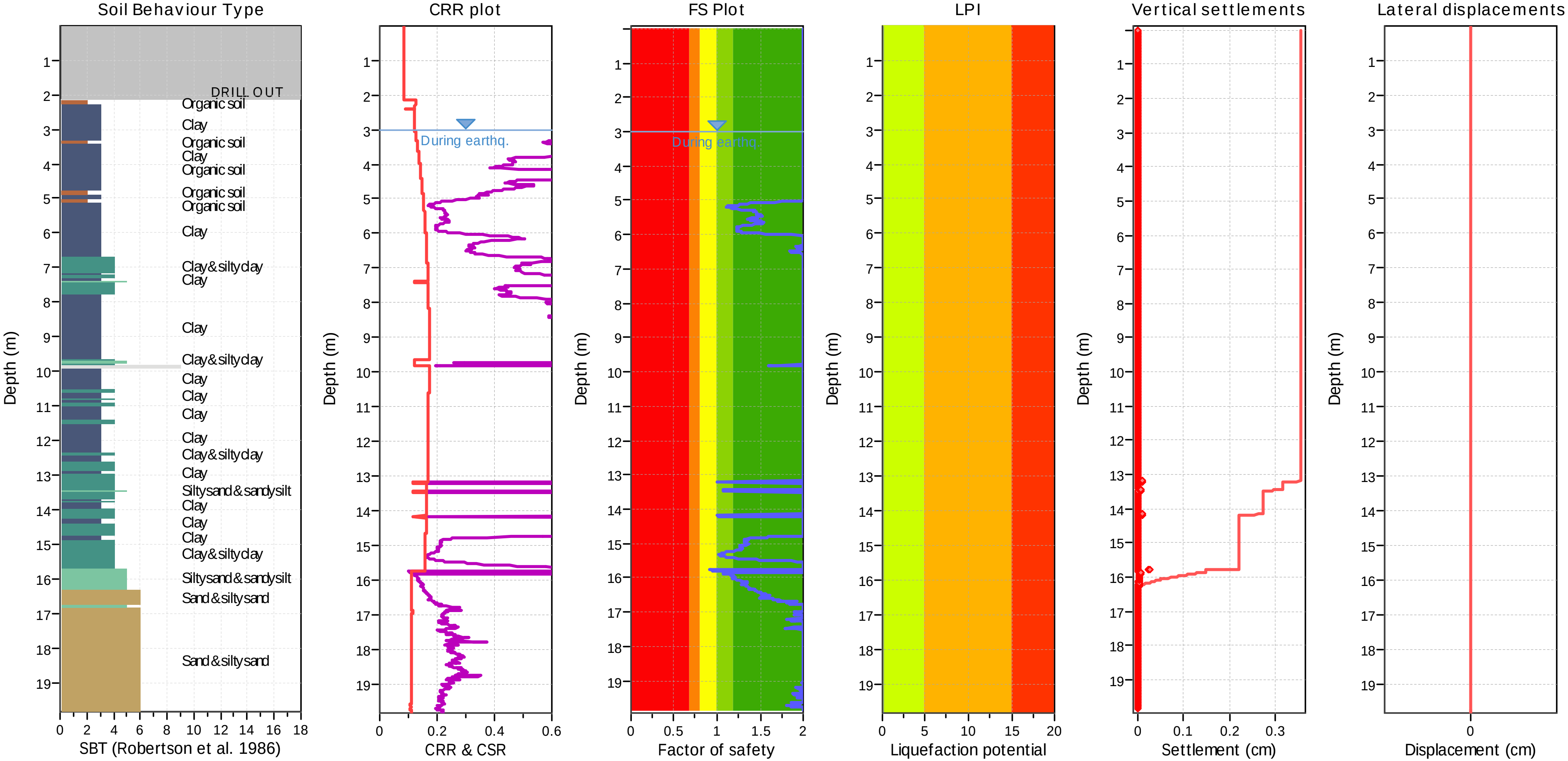


Analysis method:	I&B (2008)	G.W.T. (in-situ):	2.15 m	Use fill:	No	Clay like behavior applied:	Sand & Clay
Fines correction method:	R&W (1998)	G.W.T. (earthq.):	2.15 m	Fill height:	N/A	Limit depth applied:	No
Points to test:	Based on Ic value	Average results interval:	3	Fill weight:	N/A	Limit depth:	N/A
Earthquake magnitude M_w:	5.90	Ic cut-off value:	2.60	Trans. detect. applied:	Yes	MSF method:	Method based
Peak ground acceleration:	0.22	Unit weight calculation:	Based on SBT	K_σ applied:	Yes		

121 Rostrevor Street
Hamilton

Project: Palmer Street Development Stage 1
Location: Palmer Street

CPT: CPT-02 ULS
Total depth: 19.85 m

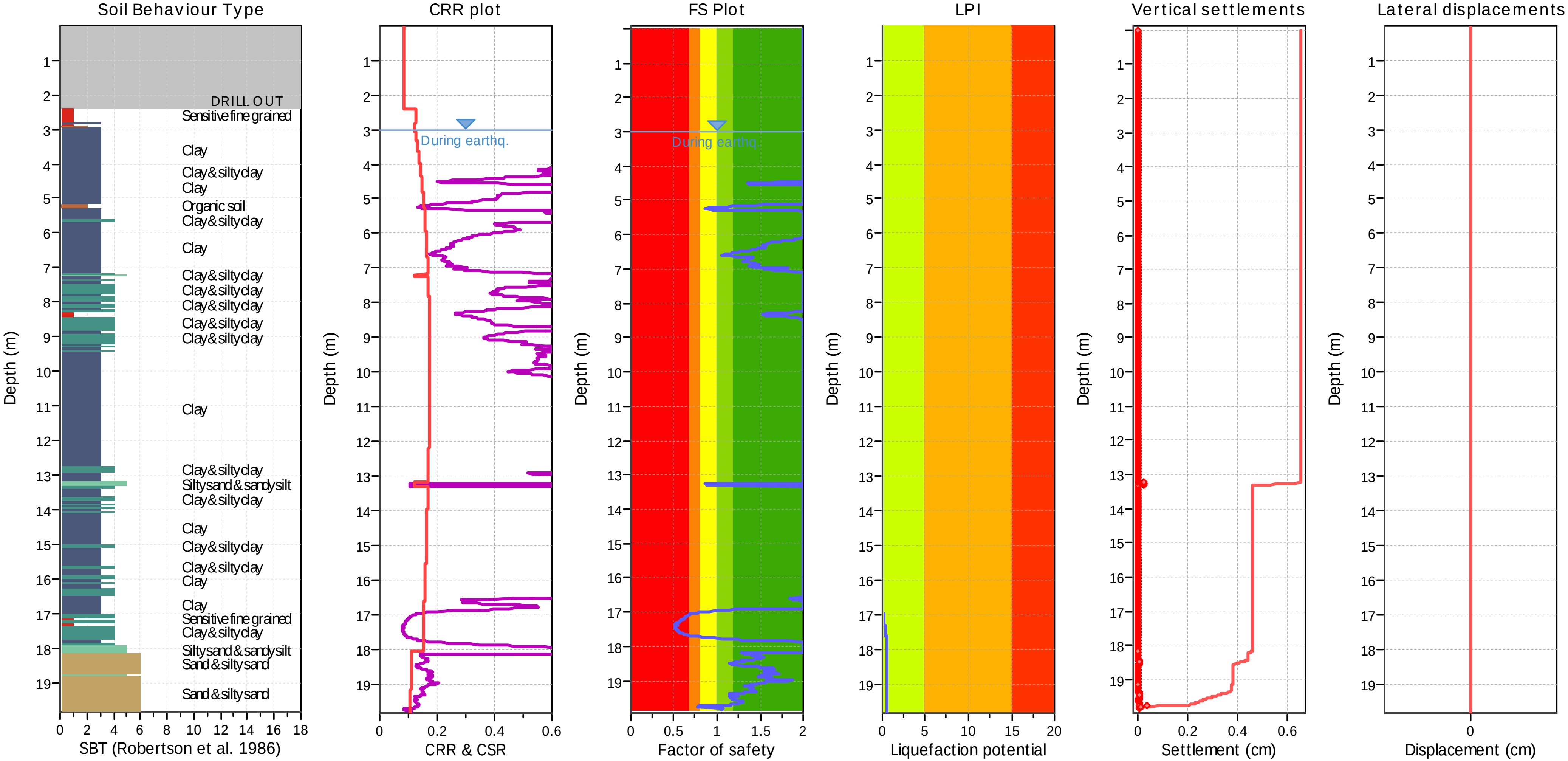


Analysis method:	I&B (2008)	G.W.T. (in-situ):	3.00 m	Use fill:	No	Clay like behavior applied:	Sand & Clay
Fines correction method:	R&W (1998)	G.W.T. (earthq.):	3.00 m	Fill height:	N/A	Limit depth applied:	No
Points to test:	Based on Ic value	Average results interval:	3	Fill weight:	N/A	Limit depth:	N/A
Earthquake magnitude M_w:	5.90	Ic cut-off value:	2.60	Trans. detect. applied:	Yes	MSF method:	Method based
Peak ground acceleration:	0.22	Unit weight calculation:	Based on SBT	K_σ applied:	Yes		

121 Rostrevor Street
Hamilton

Project: Palmer Street Development Stage 1
Location: Palmer Street

CPT: CPT-03 ULS
Total depth: 19.85 m



Analysis method:	I&B (2008)	G.W.T. (in-situ):	3.00 m	Use fill:	No	Clay like behavior applied:	Sand & Clay
Fines correction method:	R&W (1998)	G.W.T. (earthq.):	3.00 m	Fill height:	N/A	Limit depth applied:	No
Points to test:	Based on Ic value	Average results interval:	3	Fill weight:	N/A	Limit depth:	N/A
Earthquake magnitude M_w:	5.90	Ic cut-off value:	2.60	Trans. detect. applied:	Yes	MSF method:	Method based
Peak ground acceleration:	0.22	Unit weight calculation:	Based on SBT	K_σ applied:	Yes		

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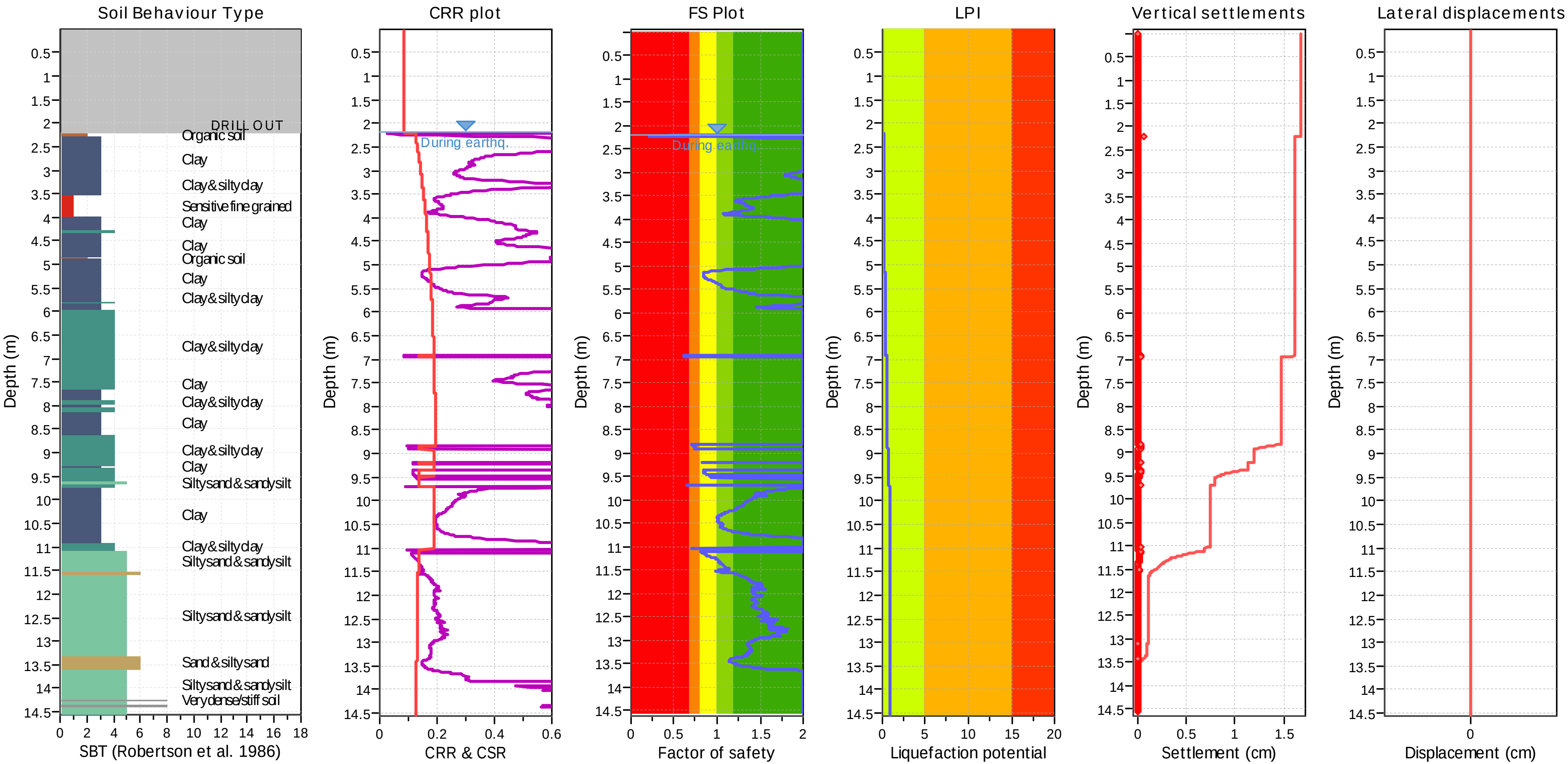
121 Rostrevor Street
Hamilton

Project: Palmer Street Development Stage 1
Location: Palmer Street

CPT: CPT-04 ULS
Total depth: 14.56 m

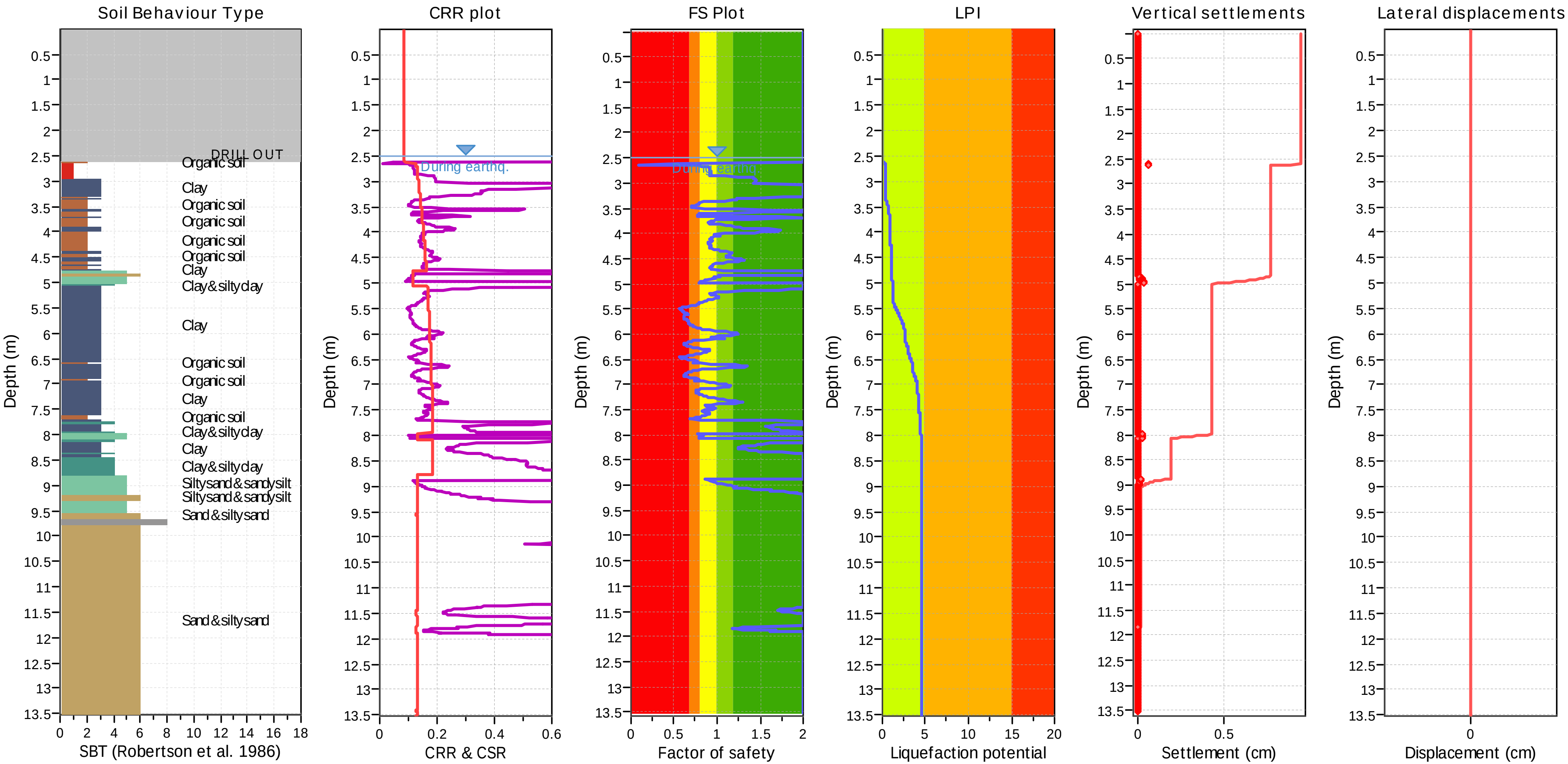


Analysis method:	I&B (2008)	G.W.T. (in-situ):	2.20 m	Use fill:	No	Clay like behavior applied:	Sand & Clay
Fines correction method:	R&W (1998)	G.W.T. (earthq.):	2.20 m	Fill height:	N/A	Limit depth applied:	No
Points to test:	Based on Ic value	Average results interval:	3	Fill weight:	N/A	Limit depth:	N/A
Earthquake magnitude M_w:	5.90	Ic cut-off value:	2.60	Trans. detect. applied:	Yes	MSF method:	Method based
Peak ground acceleration:	0.22	Unit weight calculation:	Based on SBT	K_σ applied:	Yes		

121 Rostrevor Street
Hamilton

Project: Palmer Street Development Stage 1
Location: Palmer Street

CPT: CPT-05 ULS
Total depth: 13.52 m



Analysis method:	I&B (2008)	G.W.T. (in-situ):	2.50 m	Use fill:	No	Clay like behavior applied:	Sand & Clay
Fines correction method:	R&W (1998)	G.W.T. (earthq.):	2.50 m	Fill height:	N/A	Limit depth applied:	No
Points to test:	Based on Ic value	Average results interval:	3	Fill weight:	N/A	Limit depth:	N/A
Earthquake magnitude M_w:	5.90	Ic cut-off value:	2.60	Trans. detect. applied:	Yes	MSF method:	Method based
Peak ground acceleration:	0.22	Unit weight calculation:	Based on SBT	K_σ applied:	Yes		

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Appendix D

Pile capacity

75 mm Micropiles

121 Rostrevor Street
Hamilton

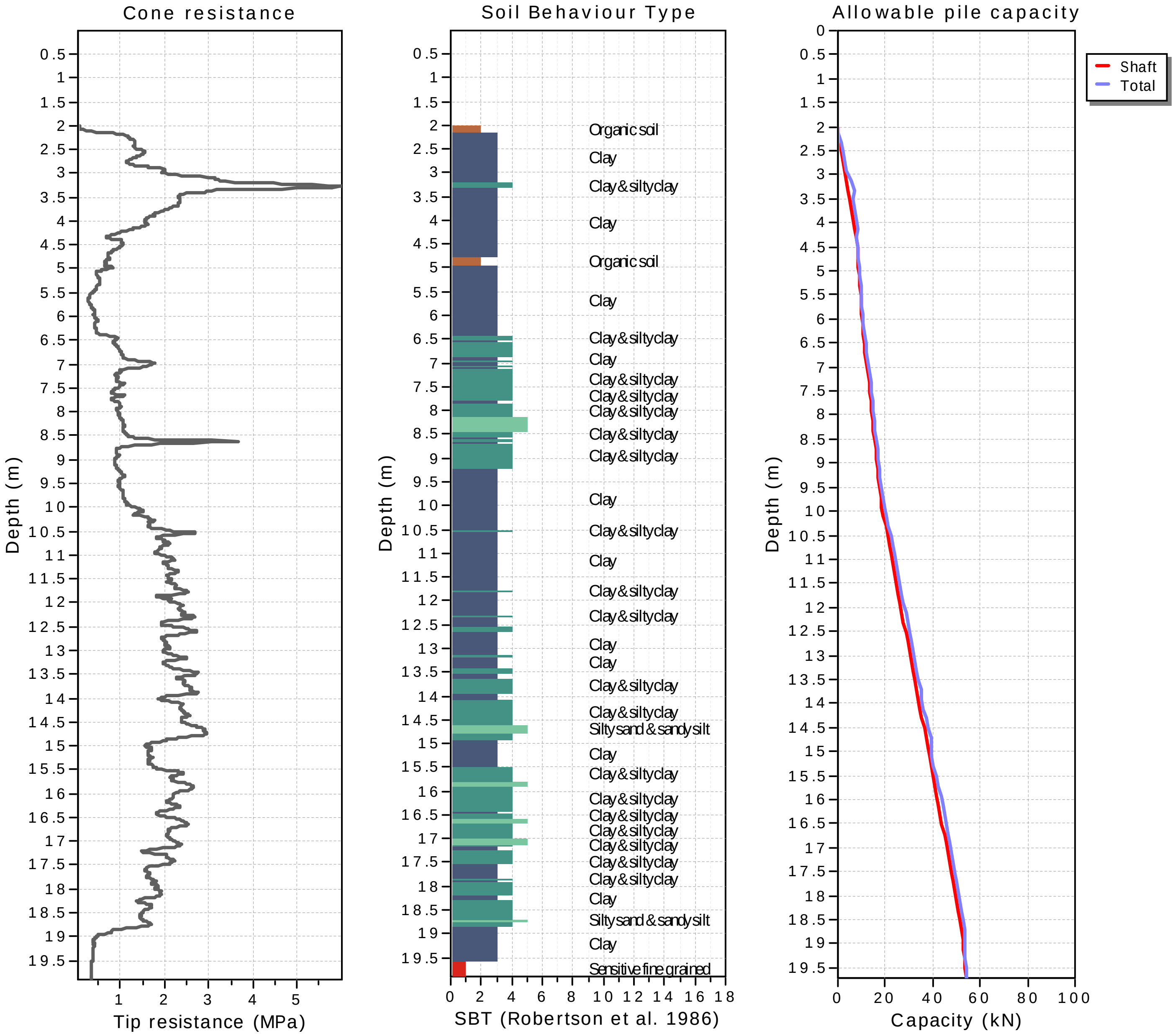
CPT: CPT-01
Total depth: 19.90 m, Date: 21/04/2015
Coords: N -38.01327, E 175.32261
Cone Type: CPTu
Cone Operator: Ground Investigation

Project: Palmer Street Development Stage 1
Location: Palmer Street

Pile properties

Shaft diameter: 0.07 m
Tip diameter: 0.07 m
Unit friction area: 0.220 m^2
Tip area: 0.004 m^2

Pile shaft Group: Group IA
Pile tip Group: Group I
Pile shaft FOS: 2.00
Pile tip FOS: 2.00



Pile group for bearing capacity factor k_c

- Group I: plain bored piles; mud bored piles; micro piles (grouted under low pressure); cased bored piles; hollow bored piles; piers; barrettes
- Group II: cast screwed piles; driven precast piles; prestressed tubular piles; driven cast piles; jacked metal piles; micropiles (small diameter piles grouted under high pressure with diameter < 250 mm); driven grouted piles (low pressure grouting); driven metal piles; driven rammed piles; jacket concrete piles; high pressure grouted piles of large diameter

Pile group for friction coefficient alpha

- Group IA: plain bored piles; mud bored piles; hollow auger bored piles; micro piles (grouted under low pressure); cast screwed piles; piers; barrettes
- Group IB: cased bored piles; driven cast piles
- Group IIA: driven precast piles; prestresses tubular piles; jacket concrete piles
- Group IIB: driven metal piles; jacked metal piles

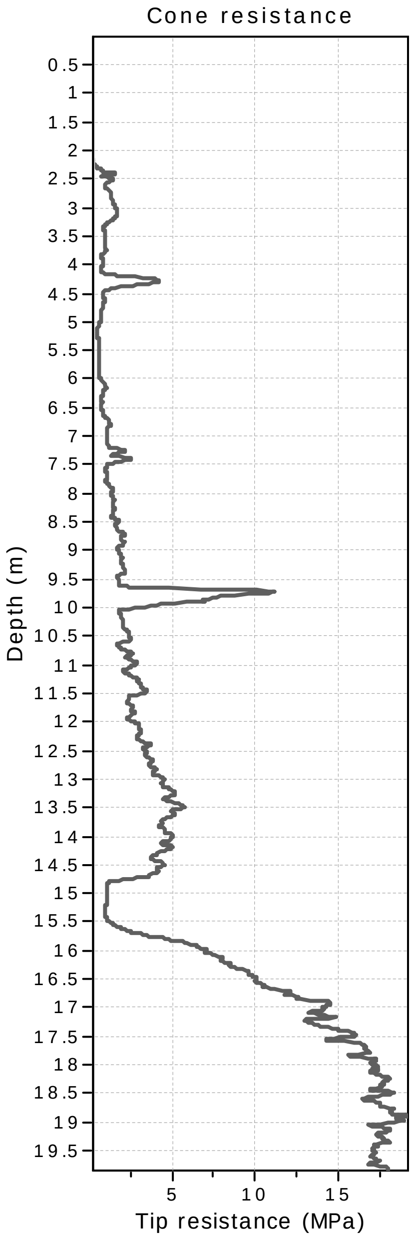
121 Rostrevor Street
Hamilton

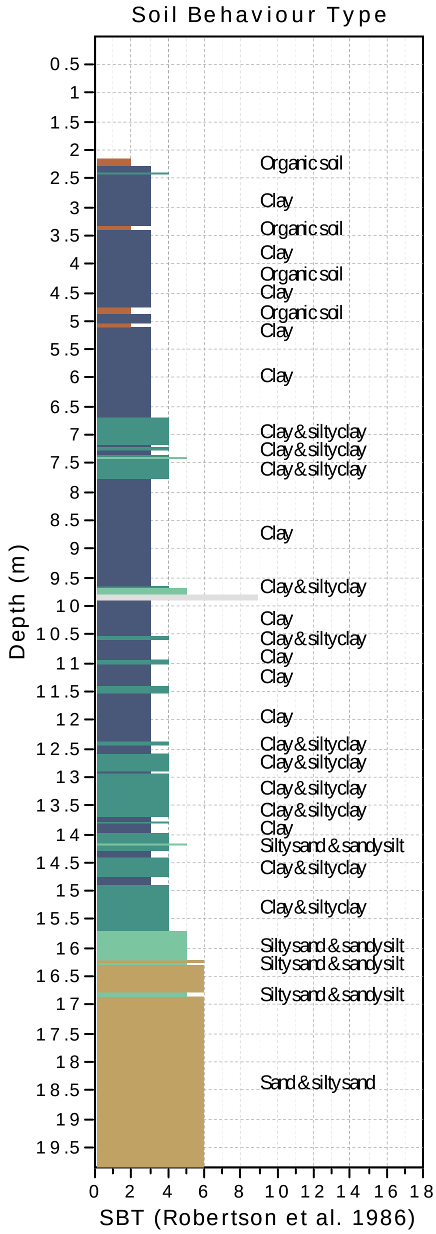
CPT: CPT-02
Total depth: 19.85 m, Date: 20/04/2015
Coords: N -38.01296, E 175.32293
Cone Type: CPTu
Cone Operator: Ground Investigation

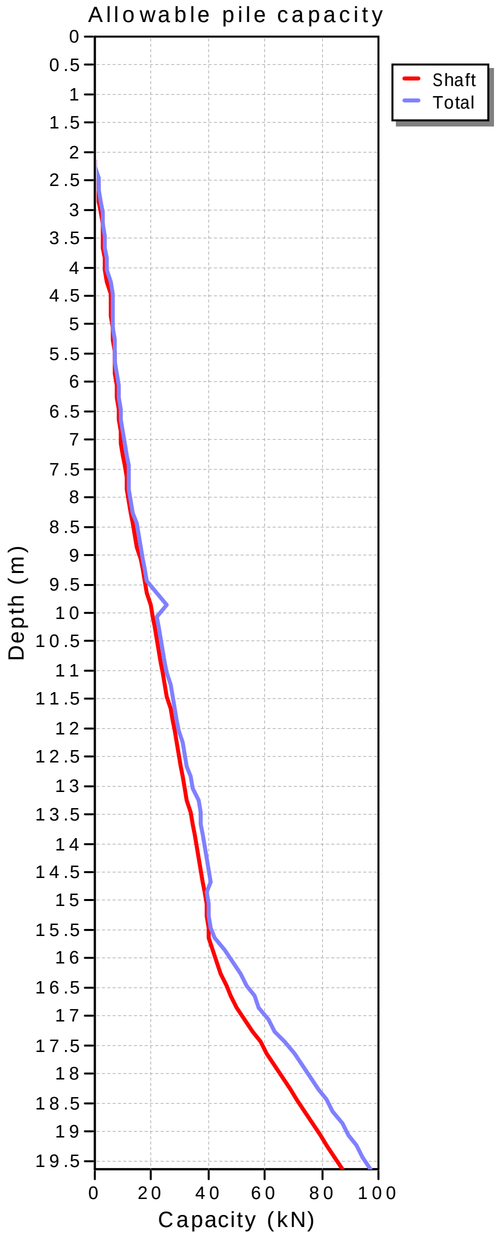
Project: Palmer Street Development Stage 1
Location: Palmer Street

Pile properties

Shaft diameter:	0.07 m	Pile shaft Group:	Group IA
Tip diameter:	0.07 m	Pile tip Group:	Group I
Unit friction area:	0.220 m^2	Pile shaft FOS:	2.00
Tip area:	0.004 m^2	Pile tip FOS:	2.00







Pile group for bearing capacity factor k_c

- Group I: plain bored piles; mud bored piles; micro piles (grouted under low pressure); cased bored piles; hollow bored piles; piers; barrettes
- Group II: cast screwed piles; driven precast piles; prestressed tubular piles; driven cast piles; jacked metal piles; micropiles (small diameter piles grouted under high pressure with diameter < 250 mm); driven grouted piles (low pressure grouting); driven metal piles; driven rammed piles; jacket concrete piles; high pressure grouted piles of large diameter

Pile group for friction coefficient alpha

- Group IA: plain bored piles; mud bored piles; hollow auger bored piles; micro piles (grouted under low pressure); cast screwed piles; piers; barrettes
- Group IB: cased bored piles; driven cast piles
- Group IIA: driven precast piles; prestresses tubular piles; jacket concrete piles
- Group IIB: driven metal piles; jacked metal piles

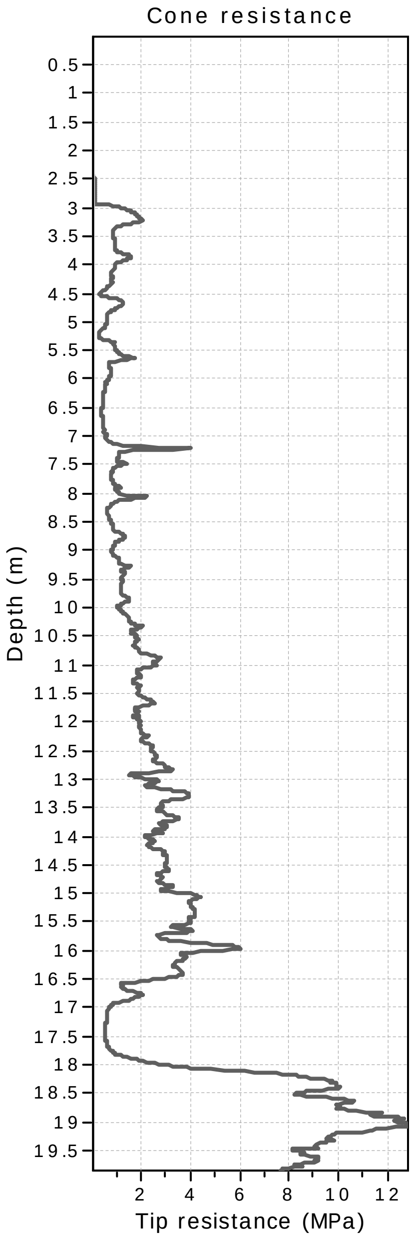
121 Rostrevor Street
Hamilton

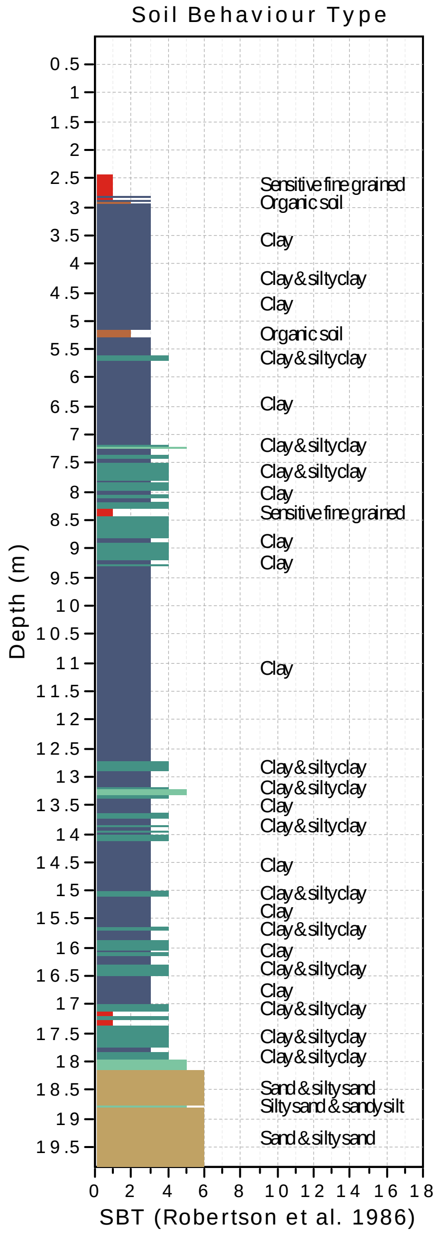
CPT: CPT-03
Total depth: 19.85 m, Date: 20/04/2015
Coords: N -38.01261, E 175.32265
Cone Type: CPTu
Cone Operator: Ground Investigation

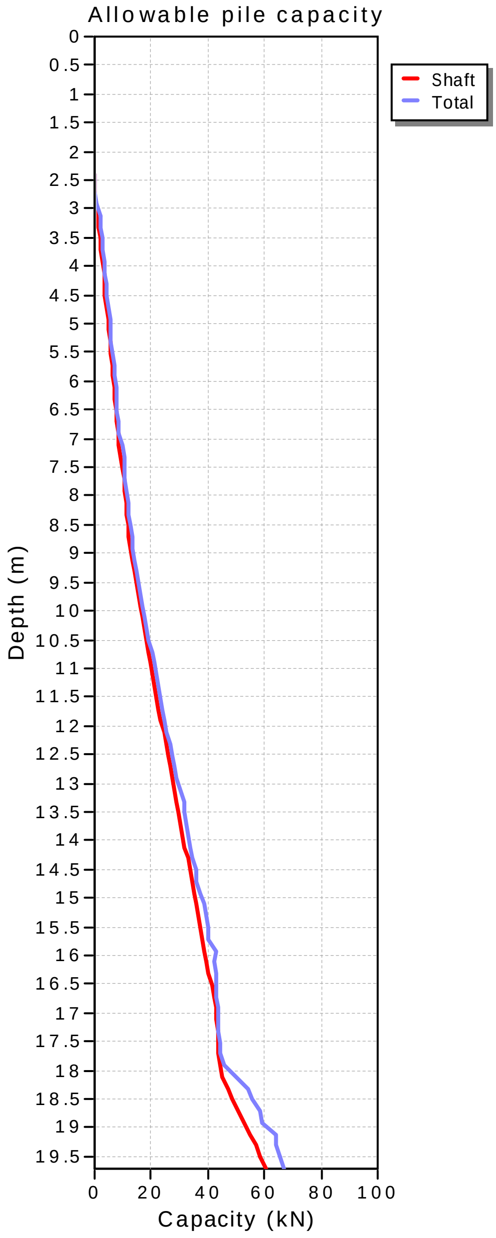
Project: Palmer Street Development Stage 1
Location: Palmer Street

Pile properties

Shaft diameter:	0.07 m	Pile shaft Group:	Group IA
Tip diameter:	0.07 m	Pile tip Group:	Group I
Unit friction area:	0.220 m^2	Pile shaft FOS:	2.00
Tip area:	0.004 m^2	Pile tip FOS:	2.00







Pile group for bearing capacity factor k_c

- Group I: plain bored piles; mud bored piles; micro piles (grouted under low pressure); cased bored piles; hollow bored piles; piers; barrettes
- Group II: cast screwed piles; driven precast piles; prestressed tubular piles; driven cast piles; jacked metal piles; micropiles (small diameter piles grouted under high pressure with diameter < 250 mm); driven grouted piles (low pressure grouting); driven metal piles; driven rammed piles; jacket concrete piles; high pressure grouted piles of large diameter

Pile group for friction coefficient alpha

- Group IA: plain bored piles; mud bored piles; hollow auger bored piles; micro piles (grouted under low pressure); cast screwed piles; piers; barrettes
- Group IB: cased bored piles; driven cast piles
- Group IIA: driven precast piles; prestresses tubular piles; jacket concrete piles
- Group IIB: driven metal piles; jacked metal piles

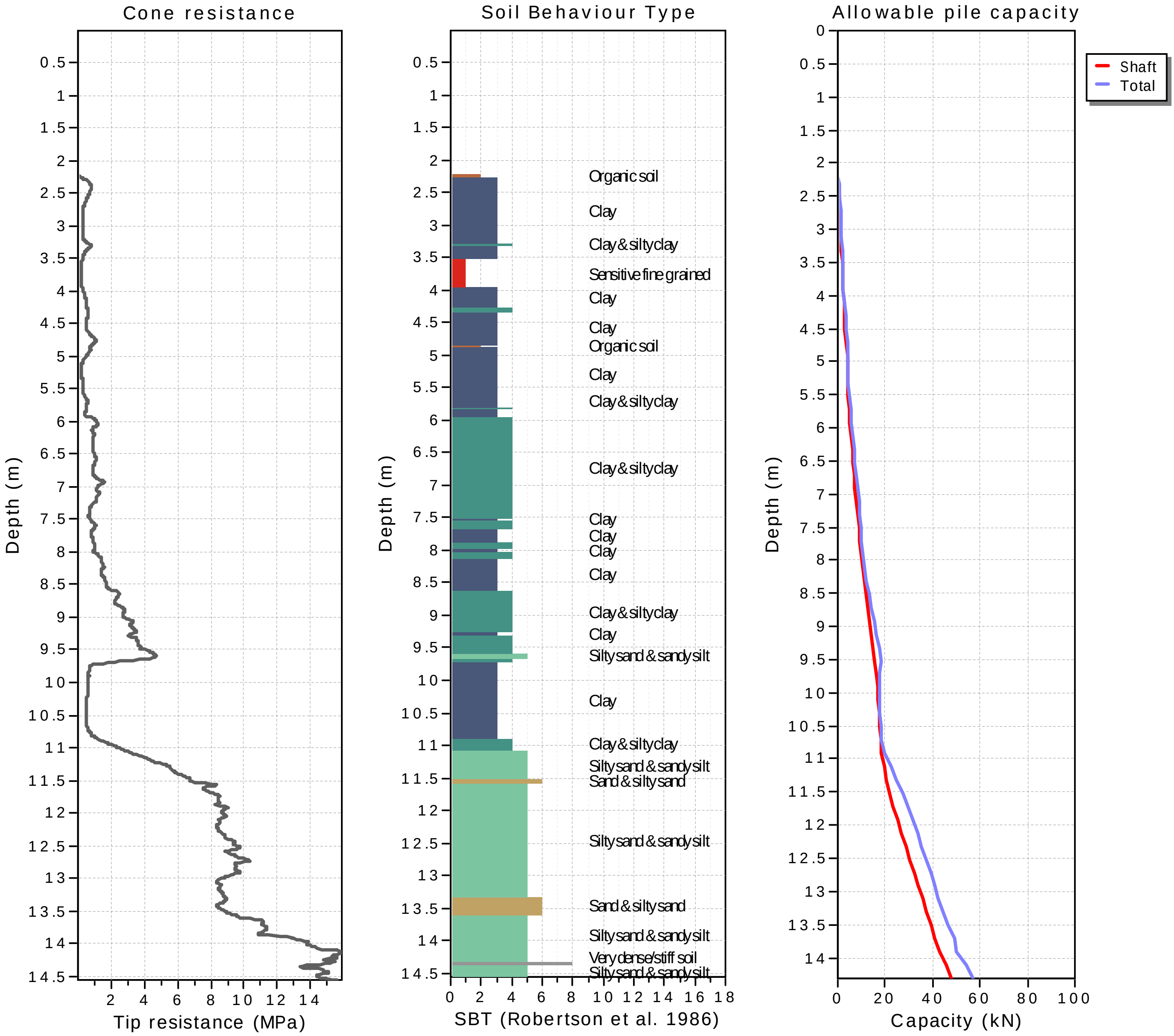
121 Rostrevor Street
Hamilton

CPT: CPT-04
Total depth: 14.56 m, Date: 21/04/2015
Coords: N -38.01227, E 175.32362
Cone Type: CPTu
Cone Operator: Ground Investigation

Project: Palmer Street Development Stage 1
Location: Palmer Street

Pile properties

Shaft diameter:	0.07 m	Pile shaft Group:	Group IA
Tip diameter:	0.07 m	Pile tip Group:	Group I
Unit friction area:	0.220 m^2	Pile shaft FOS:	2.00
Tip area:	0.004 m^2	Pile tip FOS:	2.00



Pile group for bearing capacity factor k_c

- Group I: plain bored piles; mud bored piles; micro piles (grouted under low pressure); cased bored piles; hollow bored piles; piers; barrettes
- Group II: cast screwed piles; driven precast piles; prestressed tubular piles; driven cast piles; jacked metal piles; micropiles (small diameter piles grouted under high pressure with diameter < 250 mm); driven grouted piles (low pressure grouting); driven metal piles; driven rammed piles; jacket concrete piles; high pressure grouted piles of large diameter

Pile group for friction coefficient alpha

- Group IA: plain bored piles; mud bored piles; hollow auger bored piles; micro piles (grouted under low pressure); cast screwed piles; piers; barrettes
- Group IB: cased bored piles; driven cast piles
- Group IIA: driven precast piles; prestresses tubular piles; jacket concrete piles
- Group IIB: driven metal piles; jacked metal piles

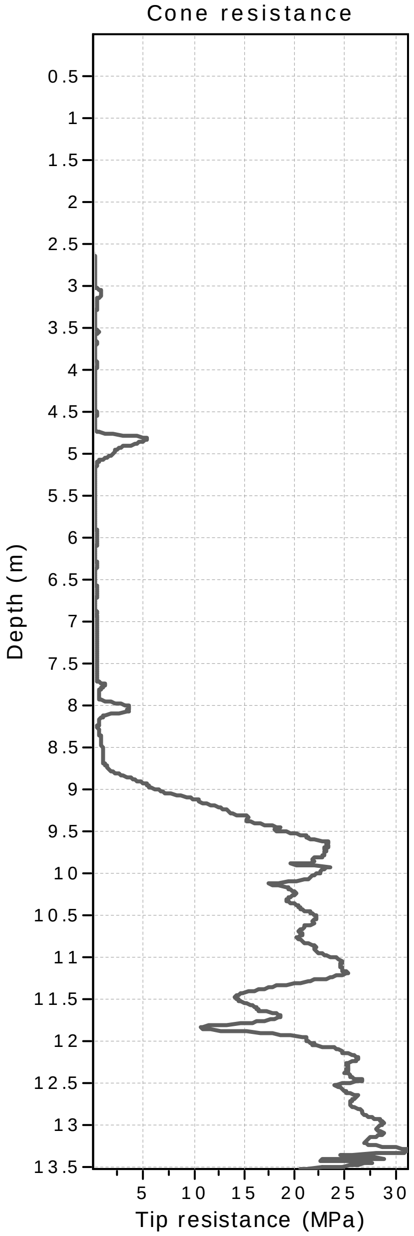
121 Rostrevor Street
Hamilton

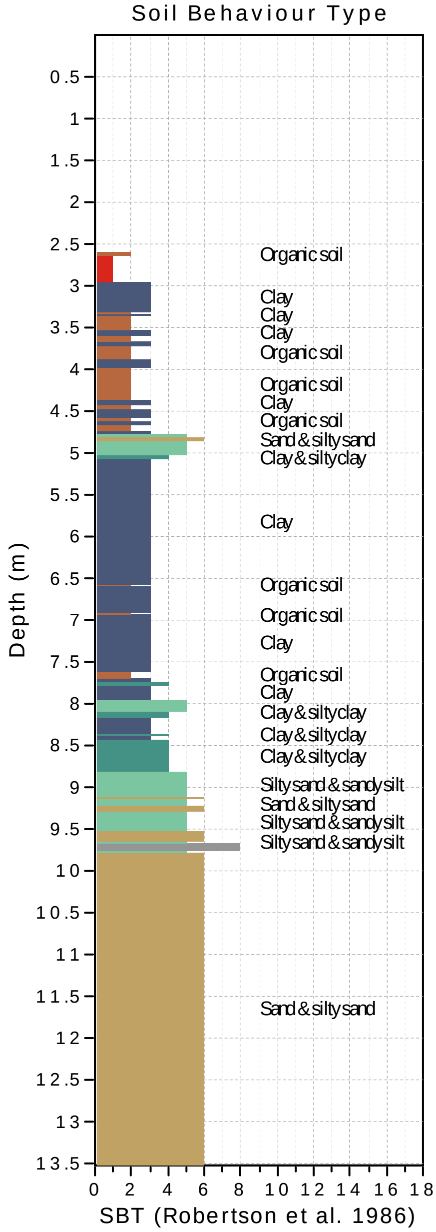
CPT: CPT-05
Total depth: 13.52 m, Date: 20/04/2015
Coords: -38.012290, 175.323870
Cone Type: CPTu
Cone Operator: Ground Investigation

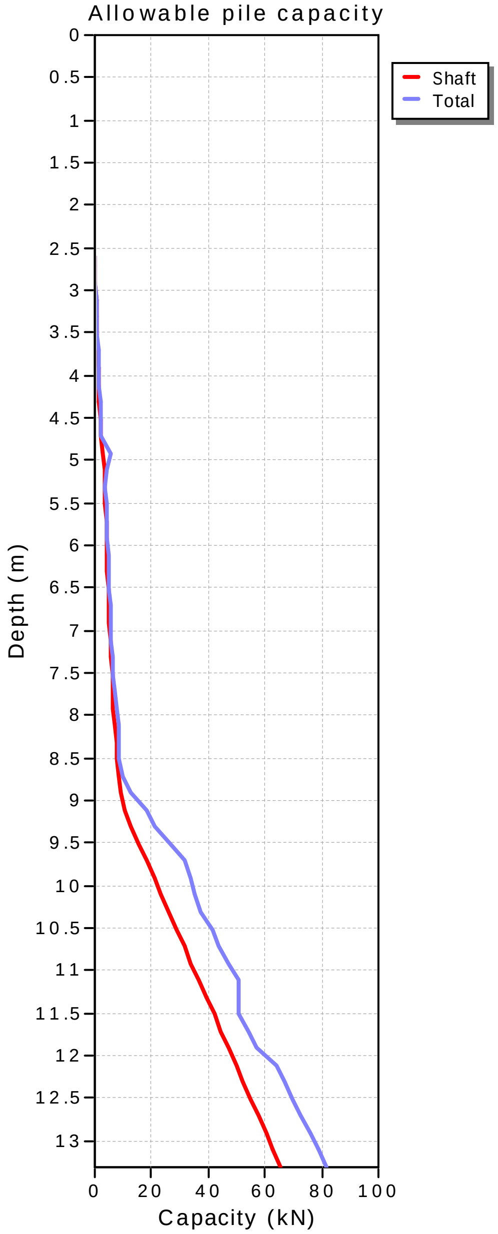
Project: Palmer Street Development Stage 1
Location: Palmer Street

Pile properties

Shaft diameter:	0.07 m	Pile shaft Group:	Group IA
Tip diameter:	0.07 m	Pile tip Group:	Group I
Unit friction area:	0.220 m^2	Pile shaft FOS:	2.00
Tip area:	0.004 m^2	Pile tip FOS:	2.00







Pile group for bearing capacity factor k_c

- Group I: plain bored piles; mud bored piles; micro piles (grouted under low pressure); cased bored piles; hollow bored piles; piers; barrettes
- Group II: cast screwed piles; driven precast piles; prestressed tubular piles; driven cast piles; jacked metal piles; micropiles (small diameter piles grouted under high pressure with diameter < 250 mm); driven grouted piles (low pressure grouting); driven metal piles; driven rammed piles; jacket concrete piles; high pressure grouted piles of large diameter

Pile group for friction coefficient alpha

- Group IA: plain bored piles; mud bored piles; hollow auger bored piles; micro piles (grouted under low pressure); cast screwed piles; piers; barrettes
- Group IB: cased bored piles; driven cast piles
- Group IIA: driven precast piles; prestresses tubular piles; jacket concrete piles
- Group IIB: driven metal piles; jacked metal piles

175 mm Driven Piles

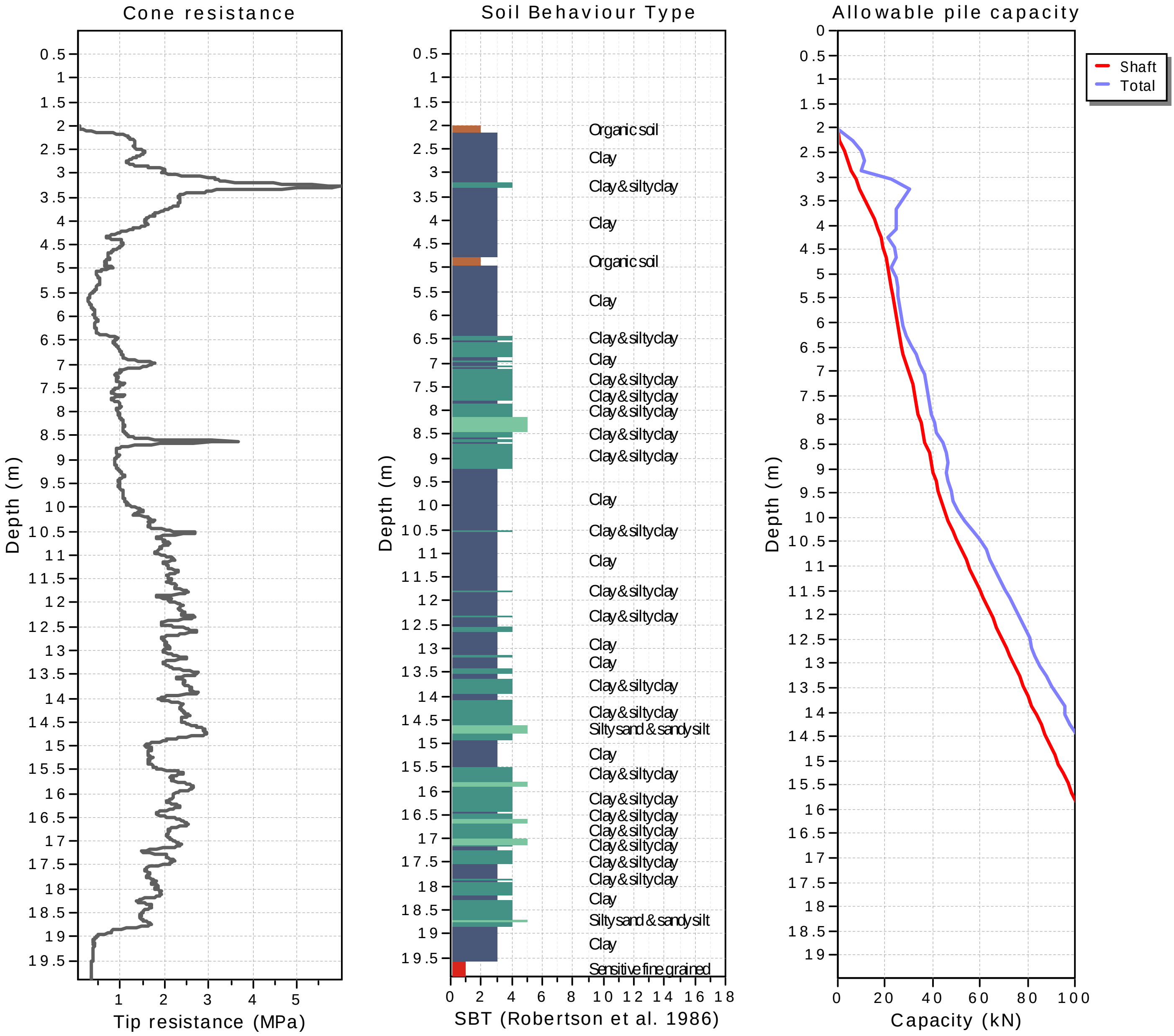
121 Rostrevor Street
Hamilton

CPT: CPT-01
Total depth: 19.90 m, Date: 21/04/2015
Coords: N -38.01327, E 175.32261
Cone Type: CPTu
Cone Operator: Ground Investigation

Project: Palmer Street Development Stage 1
Location: Palmer Street

Pile properties

Shaft diameter:	0.17 m	Pile shaft Group:	Group IIA
Tip diameter:	0.17 m	Pile tip Group:	Group II
Unit friction area:	0.534 m^2	Pile shaft FOS:	2.00
Tip area:	0.023 m^2	Pile tip FOS:	2.00



Pile group for bearing capacity factor k_c

- Group I: plain bored piles; mud bored piles; micro piles (grouted under low pressure); cased bored piles; hollow bored piles; piers; barrettes
- Group II: cast screwed piles; driven precast piles; prestressed tubular piles; driven cast piles; jacked metal piles; micropiles (small diameter piles grouted under high pressure with diameter < 250 mm); driven grouted piles (low pressure grouting); driven metal piles; driven rammed piles; jacket concrete piles; high pressure grouted piles of large diameter

Pile group for friction coefficient alpha

- Group IA: plain bored piles; mud bored piles; hollow auger bored piles; micro piles (grouted under low pressure); cast screwed piles; piers; barrettes
- Group IB: cased bored piles; driven cast piles
- Group IIA: driven precast piles; prestresses tubular piles; jacket concrete piles
- Group IIB: driven metal piles; jacked metal piles

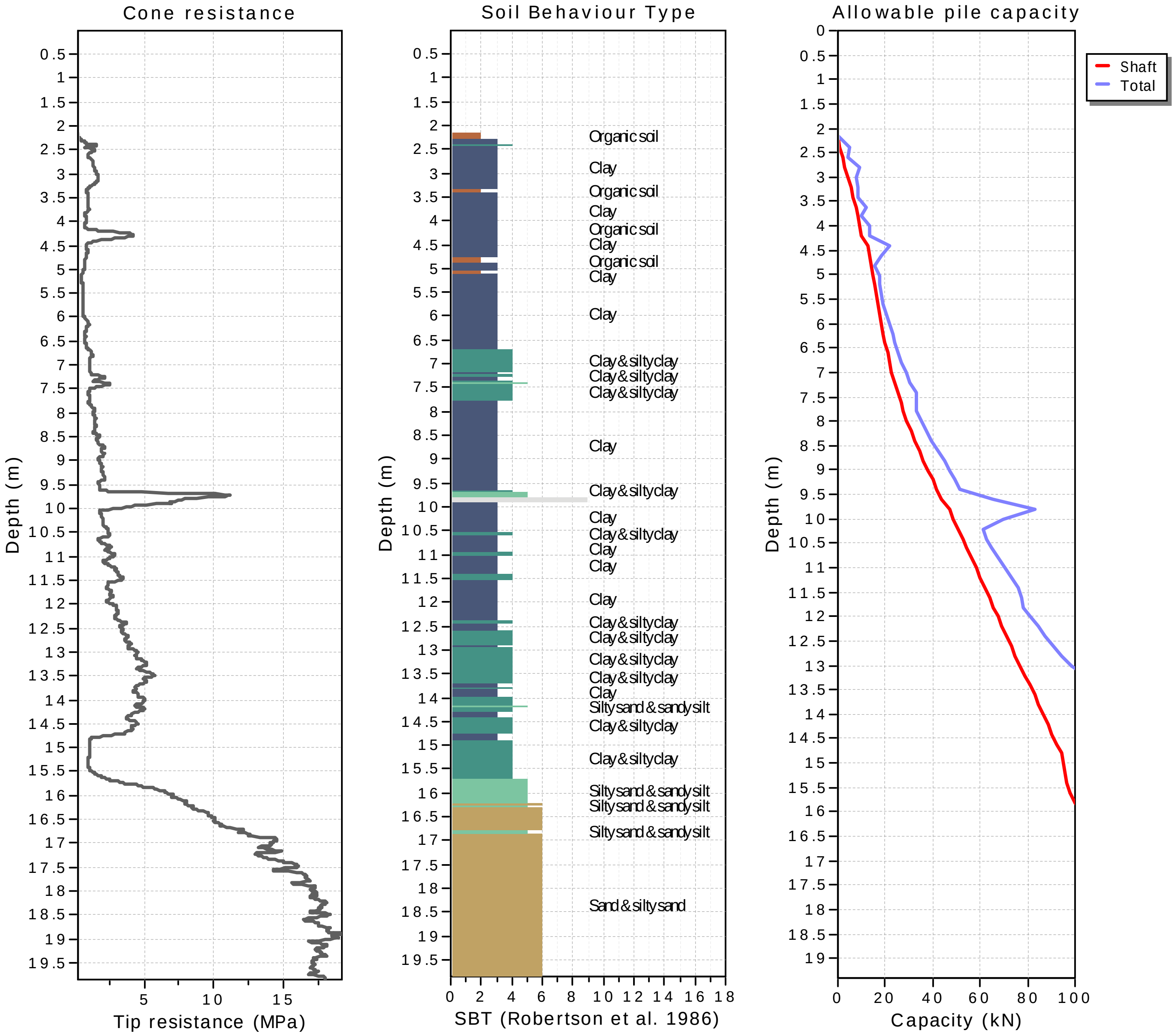
121 Rostrevor Street
Hamilton

CPT: CPT-02
Total depth: 19.85 m, Date: 20/04/2015
Coords: N -38.01296, E 175.32293
Cone Type: CPTu
Cone Operator: Ground Investigation

Project: Palmer Street Development Stage 1
Location: Palmer Street

Pile properties

Shaft diameter:	0.17 m	Pile shaft Group:	Group IIA
Tip diameter:	0.17 m	Pile tip Group:	Group II
Unit friction area:	0.534 m^2	Pile shaft FOS:	2.00
Tip area:	0.023 m^2	Pile tip FOS:	2.00



Pile group for bearing capacity factor k_c

- Group I: plain bored piles; mud bored piles; micro piles (grouted under low pressure); cased bored piles; hollow bored piles; piers; barrettes
- Group II: cast screwed piles; driven precast piles; prestressed tubular piles; driven cast piles; jacked metal piles; micropiles (small diameter piles grouted under high pressure with diameter < 250 mm); driven grouted piles (low pressure grouting); driven metal piles; driven rammed piles; jacket concrete piles; high pressure grouted piles of large diameter

Pile group for friction coefficient alpha

- Group IA: plain bored piles; mud bored piles; hollow auger bored piles; micro piles (grouted under low pressure); cast screwed piles; piers; barrettes
- Group IB: cased bored piles; driven cast piles
- Group IIA: driven precast piles; prestresses tubular piles; jacket concrete piles
- Group IIB: driven metal piles; jacked metal piles

AECOM

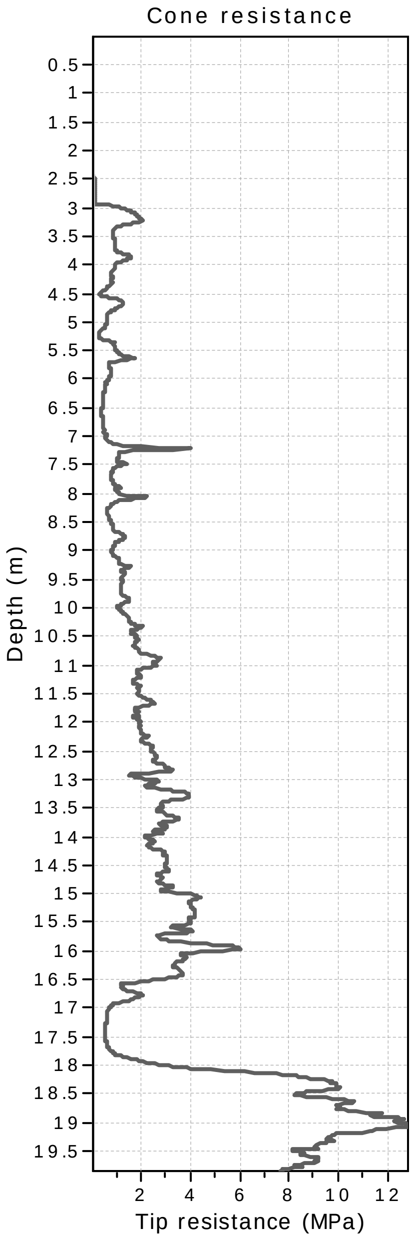
121 Rostrevor Street
Hamilton

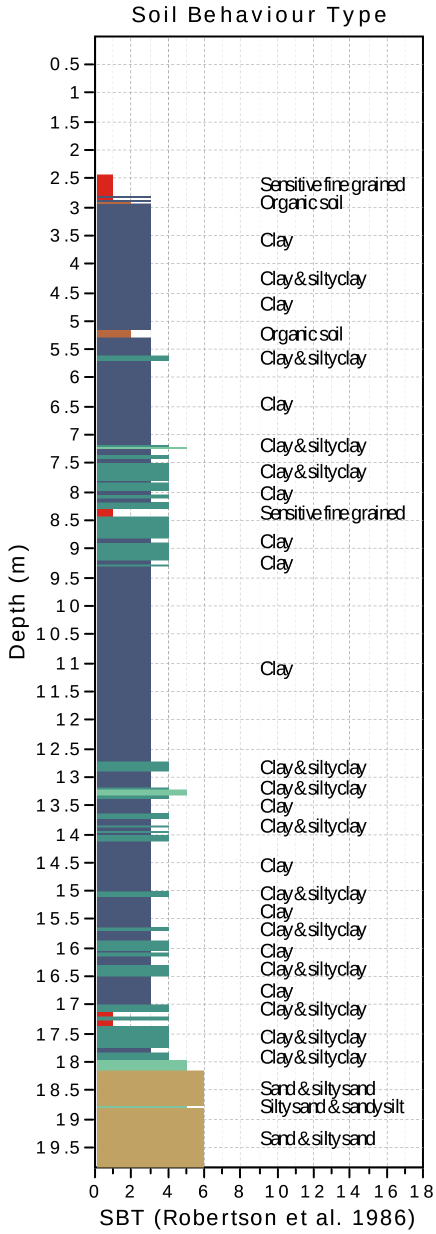
CPT: CPT-03
Total depth: 19.85 m, Date: 20/04/2015
Coords: N -38.01261, E 175.32265
Cone Type: CPTu
Cone Operator: Ground Investigation

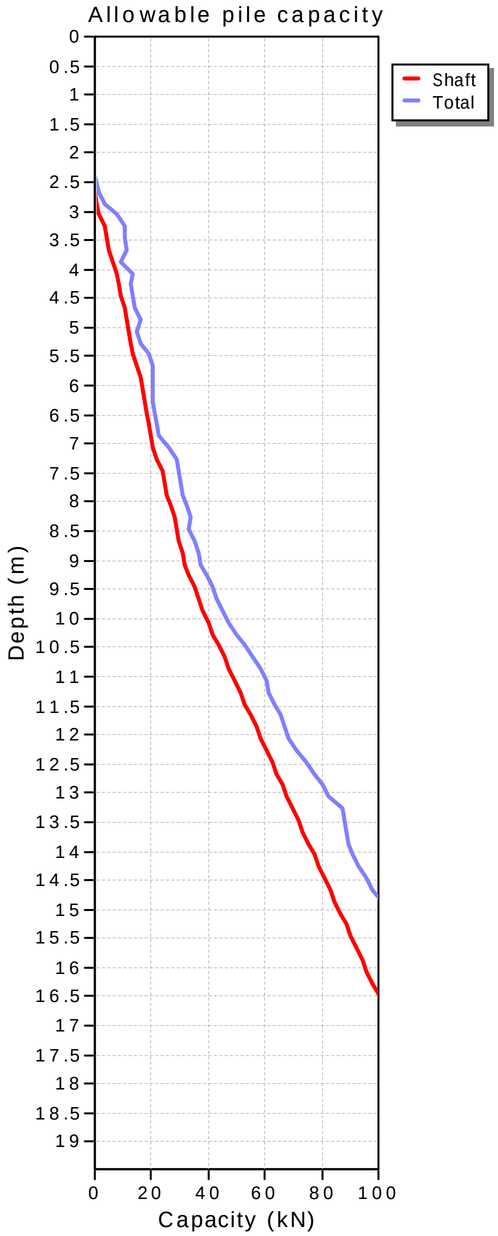
Project: Palmer Street Development Stage 1
Location: Palmer Street

Pile properties

Shaft diameter:	0.17 m	Pile shaft Group:	Group IIA
Tip diameter:	0.17 m	Pile tip Group:	Group II
Unit friction area:	0.534 m^2	Pile shaft FOS:	2.00
Tip area:	0.023 m^2	Pile tip FOS:	2.00







Pile group for bearing capacity factor k_c

- Group I: plain bored piles; mud bored piles; micro piles (grouted under low pressure); cased bored piles; hollow bored piles; piers; barrettes
- Group II: cast screwed piles; driven precast piles; prestressed tubular piles; driven cast piles; jacked metal piles; micropiles (small diameter piles grouted under high pressure with diameter < 250 mm); driven grouted piles (low pressure grouting); driven metal piles; driven rammed piles; jacket concrete piles; high pressure grouted piles of large diameter

Pile group for friction coefficient alpha

- Group IA: plain bored piles; mud bored piles; hollow auger bored piles; micro piles (grouted under low pressure); cast screwed piles; piers; barrettes
- Group IB: cased bored piles; driven cast piles
- Group IIA: driven precast piles; prestresses tubular piles; jacket concrete piles
- Group IIB: driven metal piles; jacked metal piles

AECOM

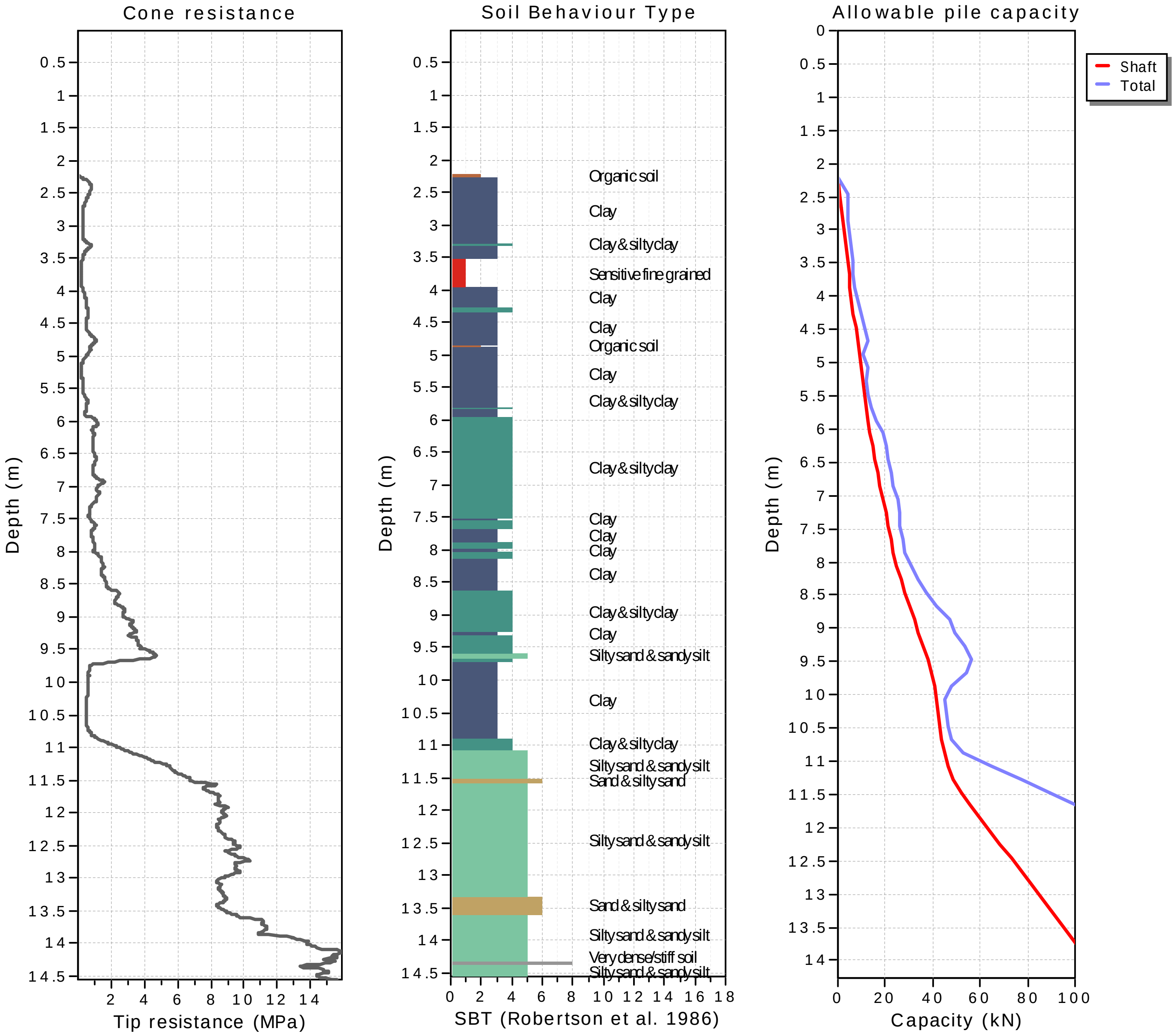
121 Rostrevor Street
Hamilton

CPT: CPT-04
Total depth: 14.56 m, Date: 21/04/2015
Coords: N -38.01227, E 175.32362
Cone Type: CPTu
Cone Operator: Ground Investigation

Project: Palmer Street Development Stage 1
Location: Palmer Street

Pile properties

Shaft diameter:	0.17 m	Pile shaft Group:	Group IIA
Tip diameter:	0.17 m	Pile tip Group:	Group II
Unit friction area:	0.534 m^2	Pile shaft FOS:	2.00
Tip area:	0.023 m^2	Pile tip FOS:	2.00



Pile group for bearing capacity factor k_c

- Group I: plain bored piles; mud bored piles; micro piles (grouted under low pressure); cased bored piles; hollow bored piles; piers; barrettes
- Group II: cast screwed piles; driven precast piles; prestressed tubular piles; driven cast piles; jacked metal piles; micropiles (small diameter piles grouted under high pressure with diameter < 250 mm); driven grouted piles (low pressure grouting); driven metal piles; driven rammed piles; jacket concrete piles; high pressure grouted piles of large diameter

Pile group for friction coefficient alpha

- Group IA: plain bored piles; mud bored piles; hollow auger bored piles; micro piles (grouted under low pressure); cast screwed piles; piers; barrettes
- Group IB: cased bored piles; driven cast piles
- Group IIA: driven precast piles; prestresses tubular piles; jacket concrete piles
- Group IIB: driven metal piles; jacked metal piles

121 Rostrevor Street
Hamilton

CPT: CPT-05

Total depth: 13.52 m, Date: 20/04/2015

Coords: -38.012290, 175.323870

Cone Type: CPTu

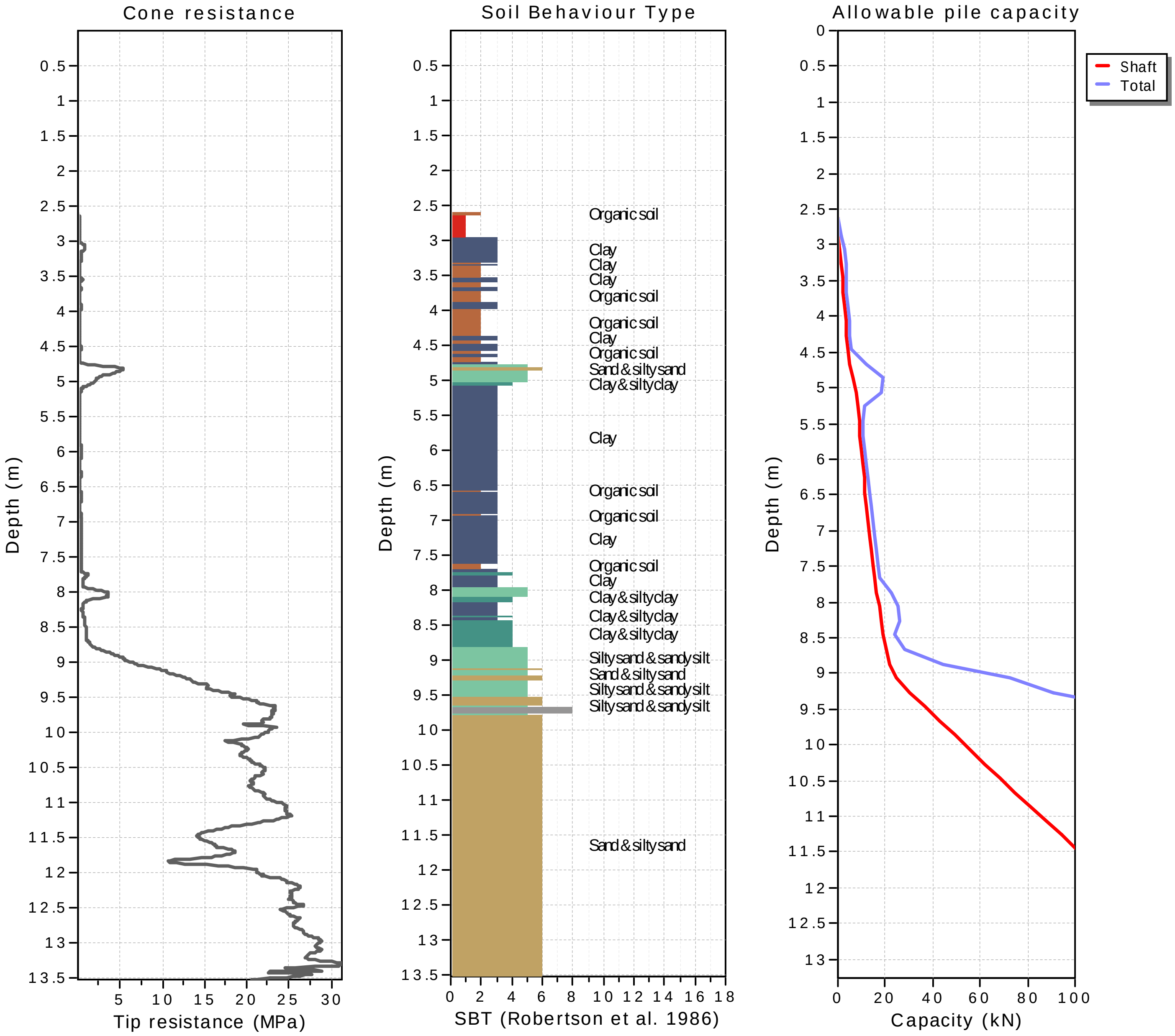
Cone Operator: Ground Investigation

Project: Palmer Street Development Stage 1

Location: Palmer Street

Pile properties

Shaft diameter:	0.17 m	Pile shaft Group:	Group IIA
Tip diameter:	0.17 m	Pile tip Group:	Group II
Unit friction area:	0.534 m^2	Pile shaft FOS:	2.00
Tip area:	0.023 m^2	Pile tip FOS:	2.00



Pile group for bearing capacity factor k_c

- Group I: plain bored piles; mud bored piles; micro piles (grouted under low pressure); cased bored piles; hollow bored piles; piers; barrettes
- Group II: cast screwed piles; driven precast piles; prestressed tubular piles; driven cast piles; jacked metal piles; micropiles (small diameter piles grouted under high pressure with diameter < 250 mm); driven grouted piles (low pressure grouting); driven metal piles; driven rammed piles; jacket concrete piles; high pressure grouted piles of large diameter

Pile group for friction coefficient alpha

- Group IA: plain bored piles; mud bored piles; hollow auger bored piles; micro piles (grouted under low pressure); cast screwed piles; piers; barrettes
- Group IB: cased bored piles; driven cast piles
- Group IIA: driven precast piles; prestresses tubular piles; jacket concrete piles
- Group IIB: driven metal piles; jacked metal piles

300 mm Bored Piles

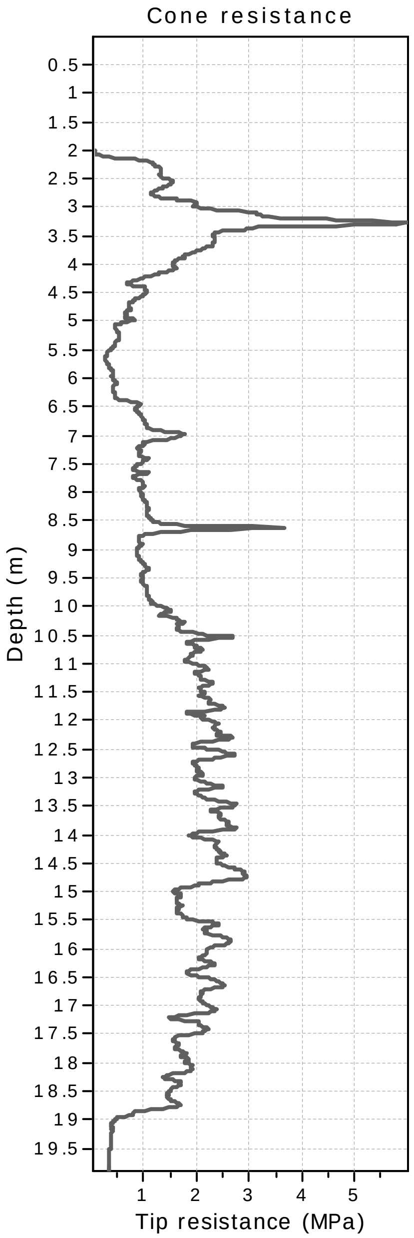
121 Rostrevor Street
Hamilton

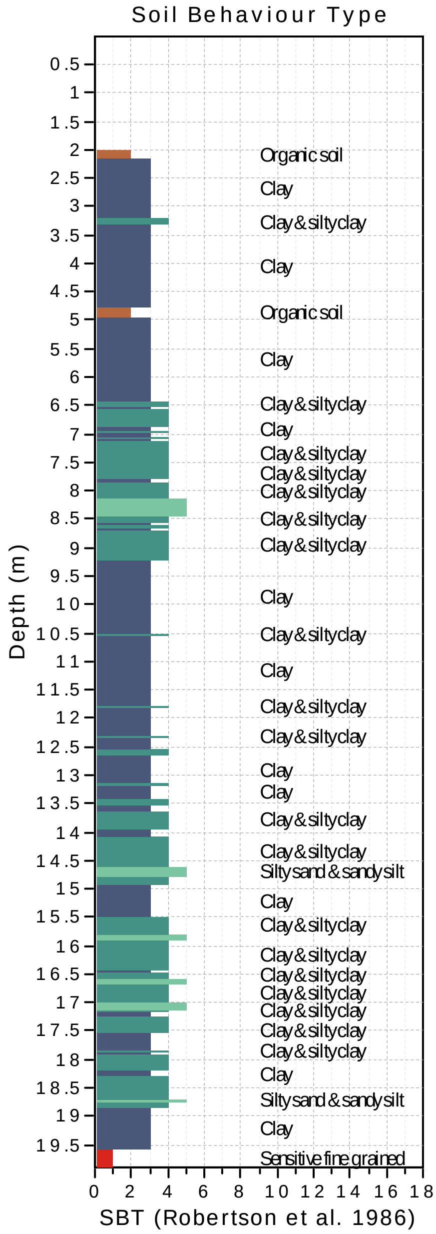
CPT: CPT-01
Total depth: 19.90 m, Date: 21/04/2015
Coords: N -38.01327, E 175.32261
Cone Type: CPTu
Cone Operator: Ground Investigation

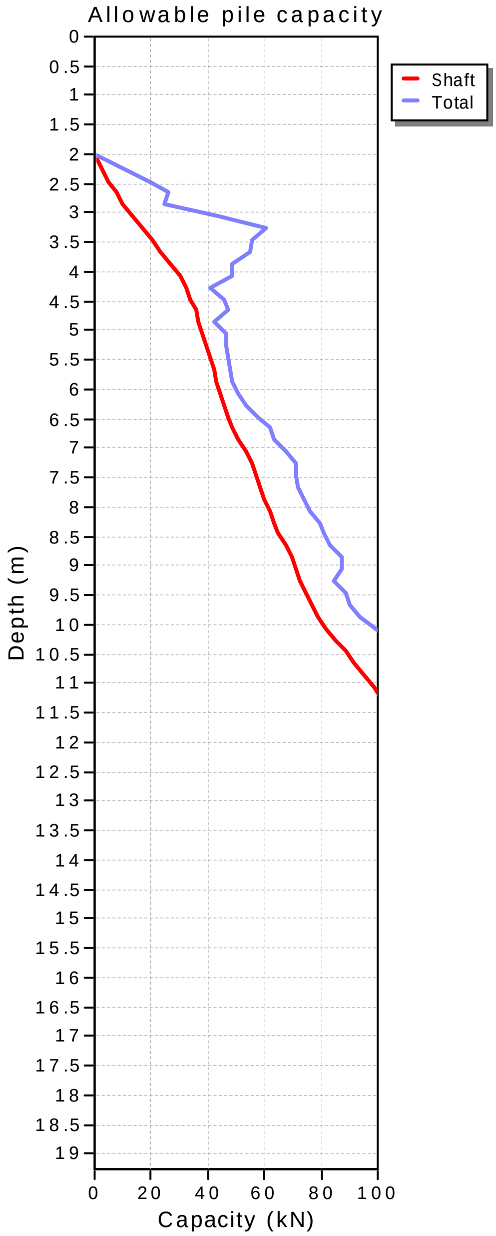
Project: Palmer Street Development Stage 1
Location: Palmer Street

Pile properties

Shaft diameter:	0.30 m	Pile shaft Group:	Group IA
Tip diameter:	0.30 m	Pile tip Group:	Group I
Unit friction area:	0.942 m^2	Pile shaft FOS:	2.00
Tip area:	0.071 m^2	Pile tip FOS:	2.00







Pile group for bearing capacity factor k_c

- Group I: plain bored piles; mud bored piles; micro piles (grouted under low pressure); cased bored piles; hollow bored piles; piers; barrettes
- Group II: cast screwed piles; driven precast piles; prestressed tubular piles; driven cast piles; jacked metal piles; micropiles (small diameter piles grouted under high pressure with diameter < 250 mm); driven grouted piles (low pressure grouting); driven metal piles; driven rammed piles; jacket concrete piles; high pressure grouted piles of large diameter

Pile group for friction coefficient alpha

- Group IA: plain bored piles; mud bored piles; hollow auger bored piles; micro piles (grouted under low pressure); cast screwed piles; piers; barrettes
- Group IB: cased bored piles; driven cast piles
- Group IIA: driven precast piles; prestresses tubular piles; jacket concrete piles
- Group IIB: driven metal piles; jacked metal piles

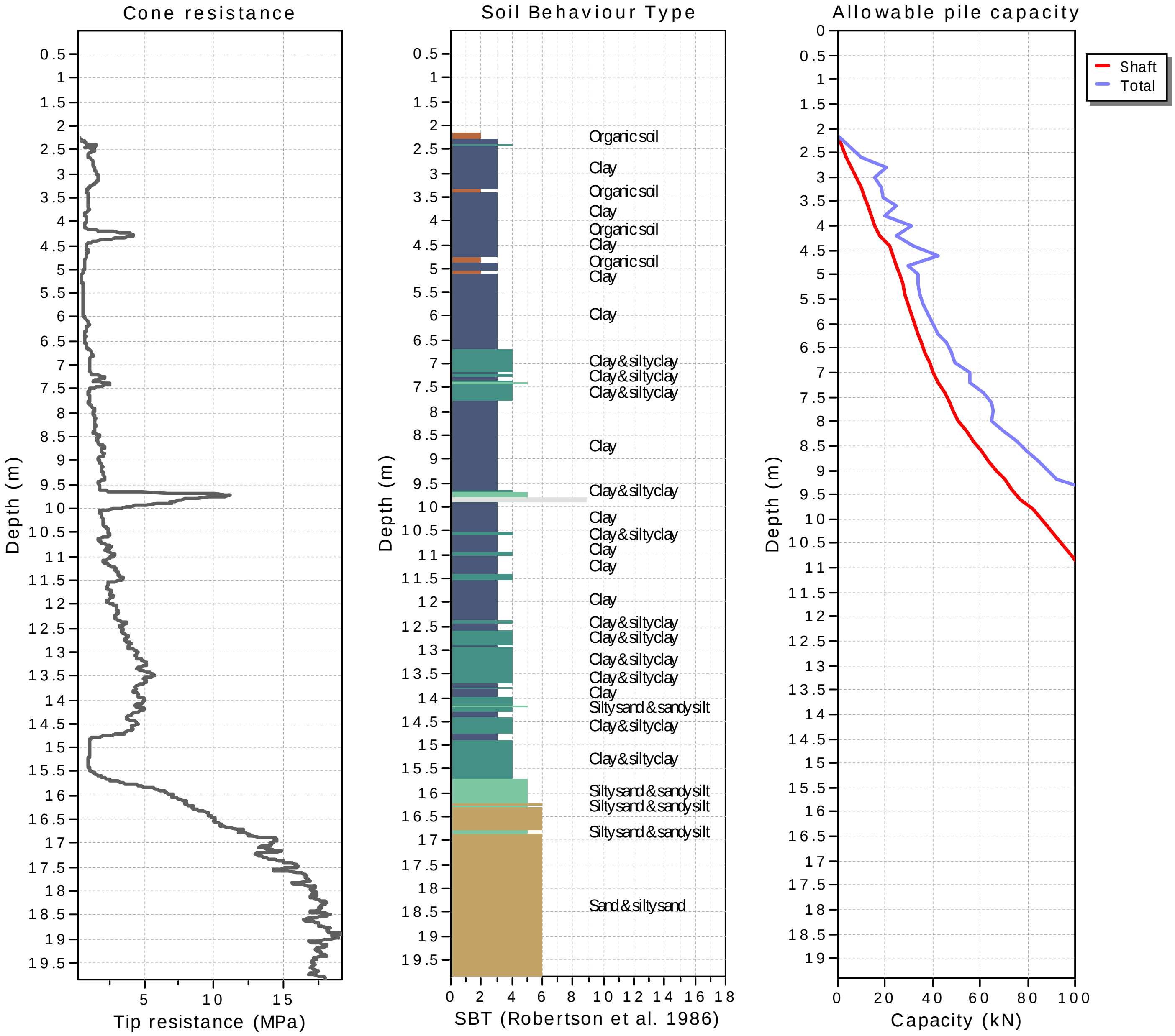
121 Rostrevor Street
Hamilton

CPT: CPT-02
Total depth: 19.85 m, Date: 20/04/2015
Coords: N -38.01296, E 175.32293
Cone Type: CPTu
Cone Operator: Ground Investigation

Project: Palmer Street Development Stage 1
Location: Palmer Street

Pile properties

Shaft diameter:	0.30 m	Pile shaft Group:	Group IA
Tip diameter:	0.30 m	Pile tip Group:	Group I
Unit friction area:	0.942 m^2	Pile shaft FOS:	2.00
Tip area:	0.071 m^2	Pile tip FOS:	2.00



Pile group for bearing capacity factor k_c

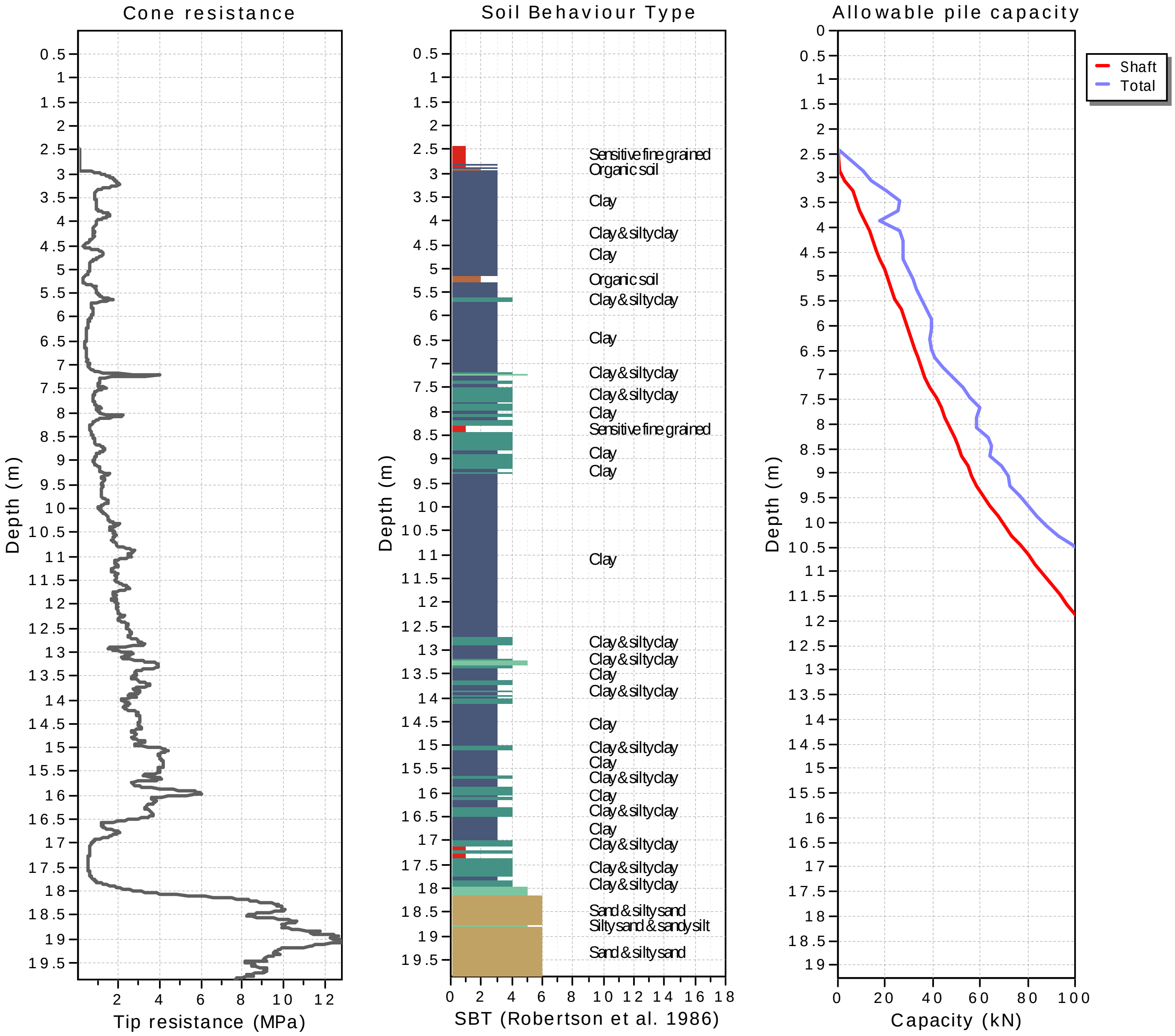
- Group I: plain bored piles; mud bored piles; micro piles (grouted under low pressure); cased bored piles; hollow bored piles; piers; barrettes
- Group II: cast screwed piles; driven precast piles; prestressed tubular piles; driven cast piles; jacked metal piles; micropiles (small diameter piles grouted under high pressure with diameter < 250 mm); driven grouted piles (low pressure grouting); driven metal piles; driven rammed piles; jacket concrete piles; high pressure grouted piles of large diameter

Pile group for friction coefficient alpha

- Group IA: plain bored piles; mud bored piles; hollow auger bored piles; micro piles (grouted under low pressure); cast screwed piles; piers; barrettes
- Group IB: cased bored piles; driven cast piles
- Group IIA: driven precast piles; prestresses tubular piles; jacket concrete piles
- Group IIB: driven metal piles; jacked metal piles

Pile properties

Shaft diameter:	0.30 m	Pile shaft Group:	Group IA
Tip diameter:	0.30 m	Pile tip Group:	Group I
Unit friction area:	0.942 m^2	Pile shaft FOS:	2.00
Tip area:	0.071 m^2	Pile tip FOS:	2.00



Pile group for bearing capacity factor k_c

- Group I: plain bored piles; mud bored piles; micro piles (grouted under low pressure); cased bored piles; hollow bored piles; piers; barrettes
- Group II: cast screwed piles; driven precast piles; prestressed tubular piles; driven cast piles; jacked metal piles; micropiles (small diameter piles grouted under high pressure with diameter < 250 mm); driven grouted piles (low pressure grouting); driven metal piles; driven rammed piles; jacket concrete piles; high pressure grouted piles of large diameter

Pile group for friction coefficient alpha

- Group IA: plain bored piles; mud bored piles; hollow auger bored piles; micro piles (grouted under low pressure); cast screwed piles; piers; barrettes
- Group IB: cased bored piles; driven cast piles
- Group IIA: driven precast piles; prestresses tubular piles; jacket concrete piles
- Group IIB: driven metal piles; jacked metal piles

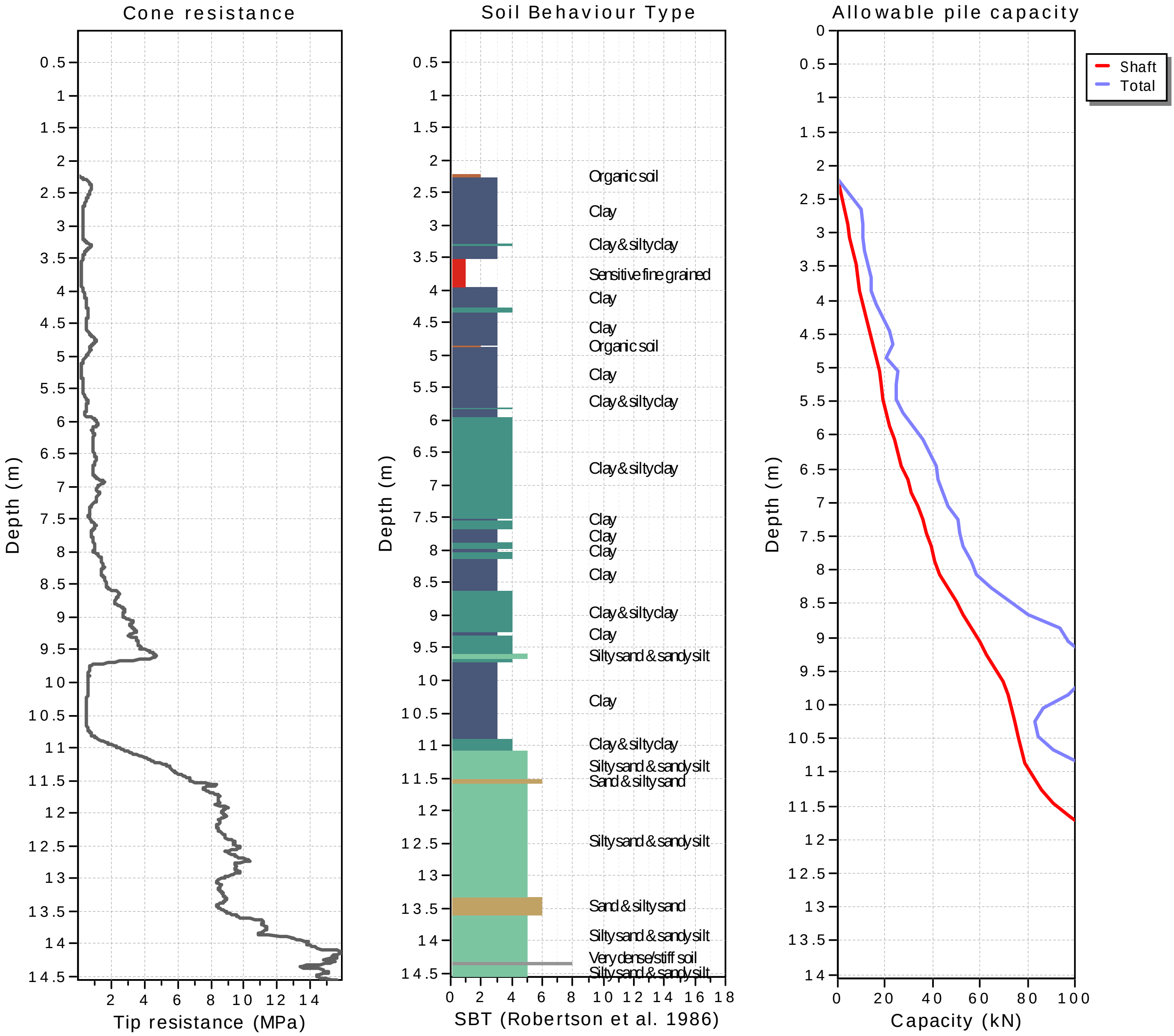
121 Rostrevor Street
Hamilton

Project: Palmer Street Development Stage 1
Location: Palmer Street

CPT: CPT-04
Total depth: 14.56 m, Date: 21/04/2015
Coords: N -38.01227, E 175.32362
Cone Type: CPTu
Cone Operator: Ground Investigation

Pile properties

Shaft diameter:	0.30 m	Pile shaft Group:	Group IA
Tip diameter:	0.30 m	Pile tip Group:	Group I
Unit friction area:	0.942 m²	Pile shaft FOS:	2.00
Tip area:	0.071 m²	Pile tip FOS:	2.00



Pile group for bearing capacity factor k_c

- Group I: plain bored piles; mud bored piles; micro piles (grouted under low pressure); cased bored piles; hollow bored piles; piers; barrettes
- Group II: cast screwed piles; driven precast piles; prestressed tubular piles; driven cast piles; jacked metal piles; micropiles (small diameter piles grouted under high pressure with diameter < 250 mm); driven grouted piles (low pressure grouting); driven metal piles; driven rammed piles; jacket concrete piles; high pressure grouted piles of large diameter

Pile group for friction coefficient alpha

- Group IA: plain bored piles; mud bored piles; hollow auger bored piles; micro piles (grouted under low pressure); cast screwed piles; piers; barrettes
- Group IB: cased bored piles; driven cast piles
- Group IIA: driven precast piles; prestresses tubular piles; jacket concrete piles
- Group IIB: driven metal piles; jacked metal piles

121 Rostrevor Street
Hamilton

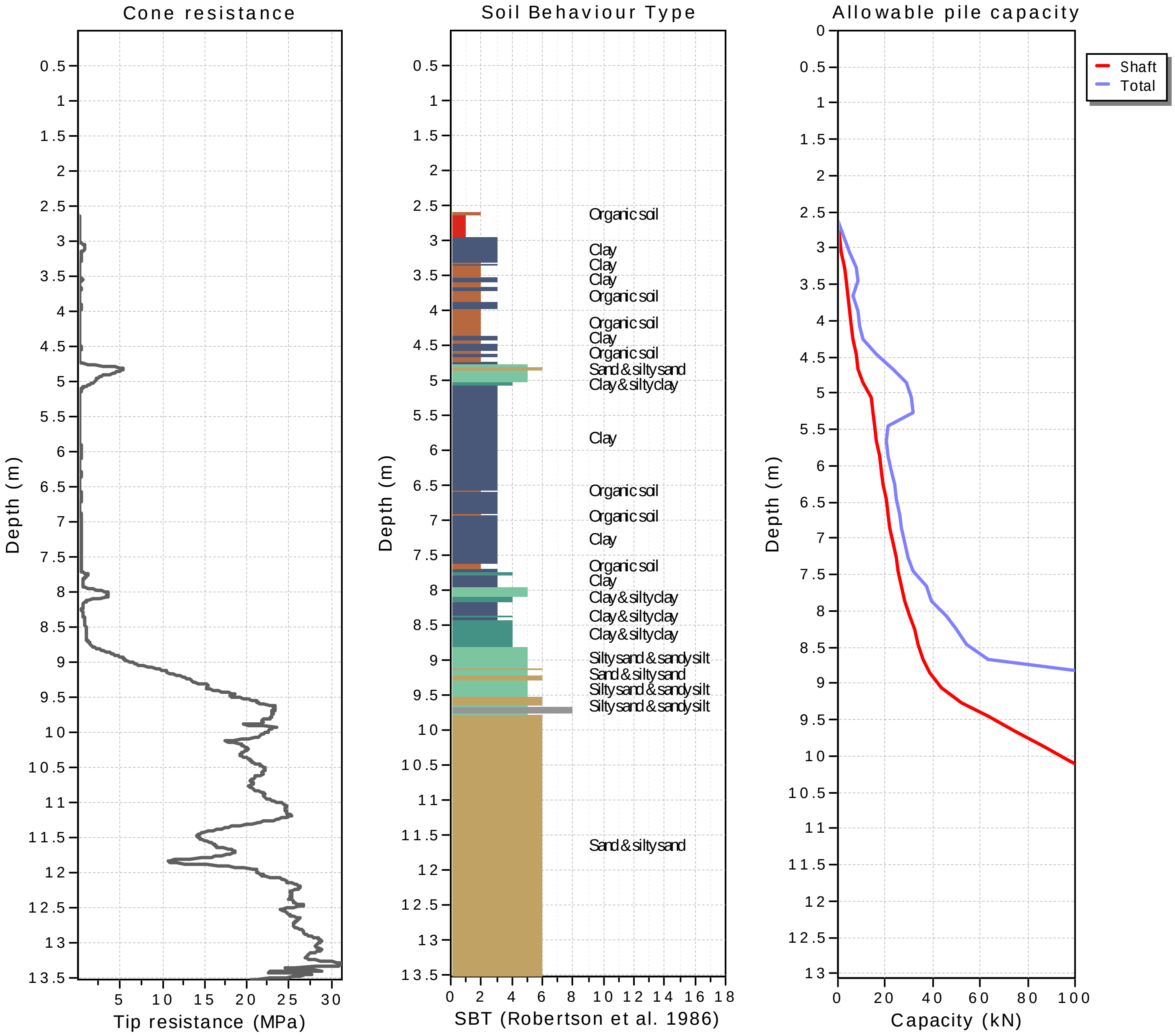
CPT: CPT-05
Total depth: 13.52 m, Date: 20/04/2015
Coords: -38.012290, 175.323870
Cone Type: CPTu
Cone Operator: Ground Investigation

Project: Palmer Street Development Stage 1
Location: Palmer Street

Pile properties

Shaft diameter: 0.30 m
Tip diameter: 0.30 m
Unit friction area: 0.942 m^2
Tip area: 0.071 m^2

Pile shaft Group: Group IA
Pile tip Group: Group I
Pile shaft FOS: 2.00
Pile tip FOS: 2.00



Pile group for bearing capacity factor k_c

- Group I: plain bored piles; mud bored piles; micro piles (grouted under low pressure); cased bored piles; hollow bored piles; piers; barrettes
- Group II: cast screwed piles; driven precast piles; prestressed tubular piles; driven cast piles; jacked metal piles; micropiles (small diameter piles grouted under high pressure with diameter < 250 mm); driven grouted piles (low pressure grouting); driven metal piles; driven rammed piles; jacket concrete piles; high pressure grouted piles of large diameter

Pile group for friction coefficient alpha

- Group IA: plain bored piles; mud bored piles; hollow auger bored piles; micro piles (grouted under low pressure); cast screwed piles; piers; barrettes
- Group IB: cased bored piles; driven cast piles
- Group IIA: driven precast piles; prestresses tubular piles; jacket concrete piles
- Group IIB: driven metal piles; jacked metal piles

Screwed Piles
400 mm Tip
100 mm Shaft

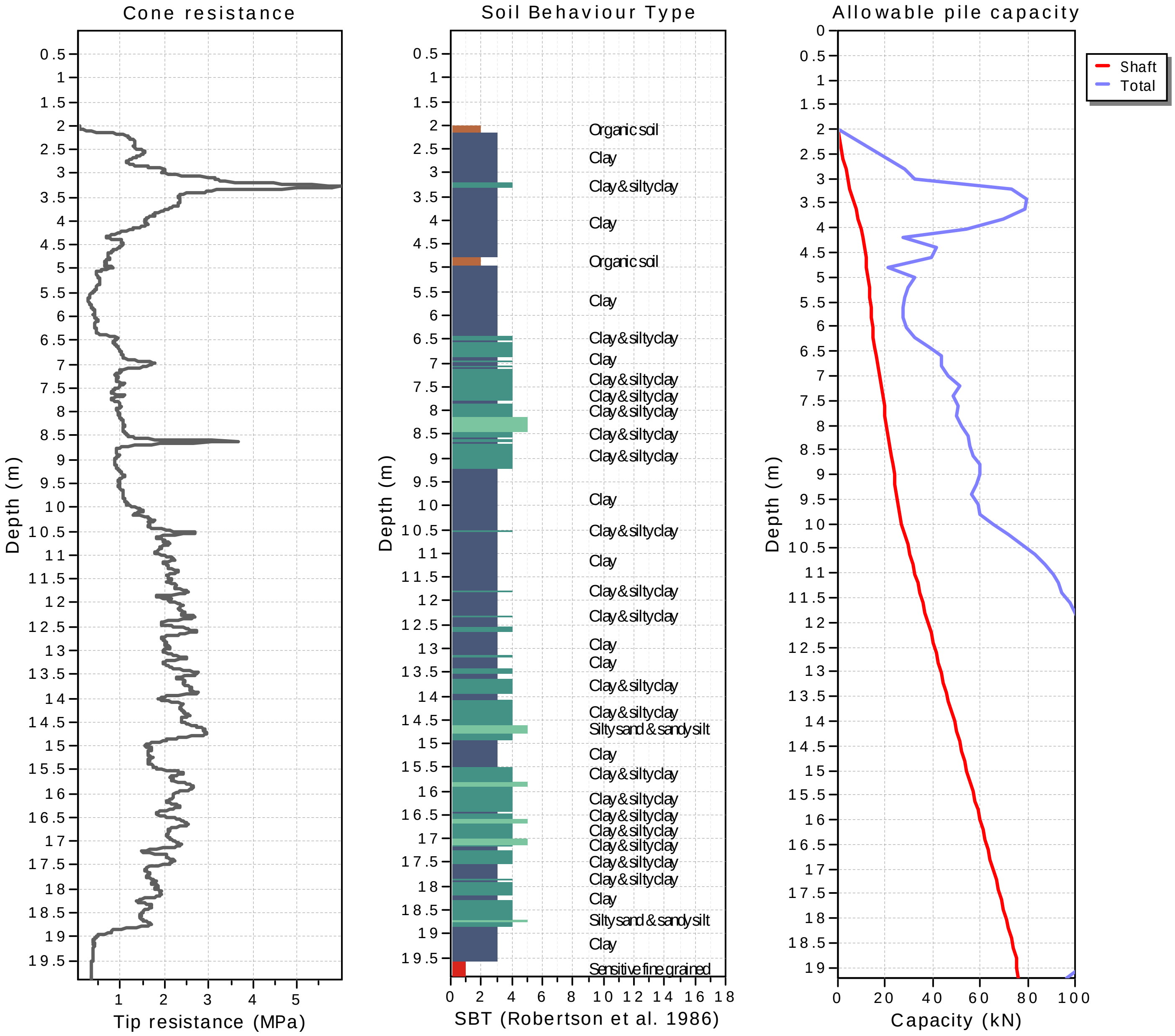
121 Rostrevor Street
Hamilton

CPT: CPT-01
Total depth: 19.90 m, Date: 21/04/2015
Coords: N -38.01327, E 175.32261
Cone Type: CPTu
Cone Operator: Ground Investigation

Project: Palmer Street Development Stage 1
Location: Palmer Street

Pile properties

Shaft diameter:	0.10 m	Pile shaft Group:	Group IA
Tip diameter:	0.40 m	Pile tip Group:	Group II
Unit friction area:	0.314 m^2	Pile shaft FOS:	2.00
Tip area:	0.126 m^2	Pile tip FOS:	2.00



Pile group for bearing capacity factor k_c

- Group I: plain bored piles; mud bored piles; micro piles (grouted under low pressure); cased bored piles; hollow bored piles; piers; barrettes
- Group II: cast screwed piles; driven precast piles; prestressed tubular piles; driven cast piles; jacked metal piles; micropiles (small diameter piles grouted under high pressure with diameter < 250 mm); driven grouted piles (low pressure grouting); driven metal piles; driven rammed piles; jacket concrete piles; high pressure grouted piles of large diameter

Pile group for friction coefficient alpha

- Group IA: plain bored piles; mud bored piles; hollow auger bored piles; micro piles (grouted under low pressure); cast screwed piles; piers; barrettes
- Group IB: cased bored piles; driven cast piles
- Group IIA: driven precast piles; prestresses tubular piles; jacket concrete piles
- Group IIB: driven metal piles; jacked metal piles

AECOM

121 Rostrevor Street
Hamilton

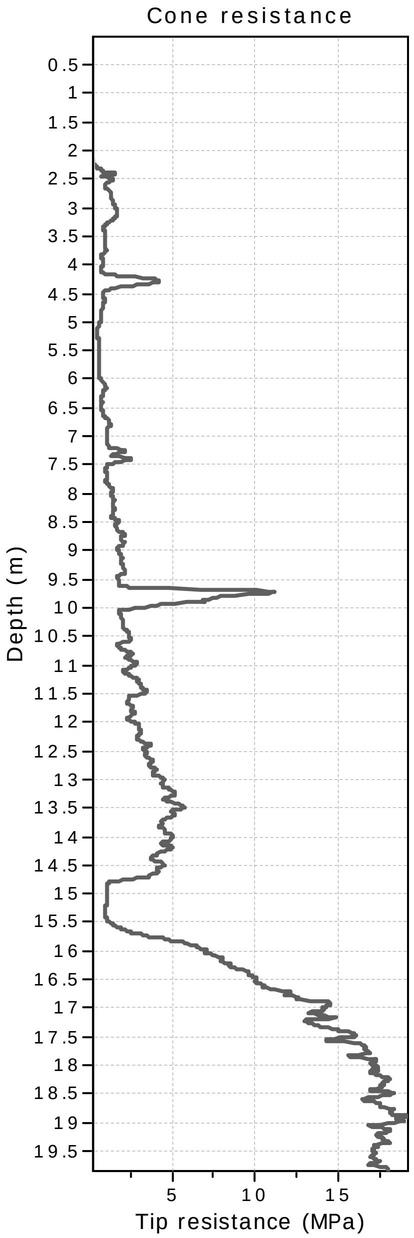
CPT: CPT-02
Total depth: 19.85 m, Date: 20/04/2015
Coords: N -38.01296, E 175.32293
Cone Type: CPTu
Cone Operator: Ground Investigation

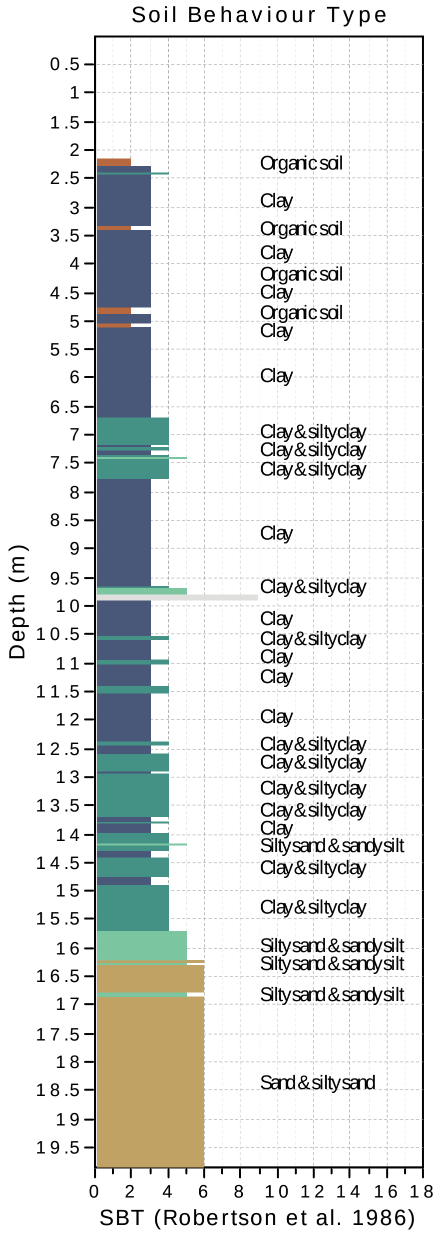
Project: Palmer Street Development Stage 1
Location: Palmer Street

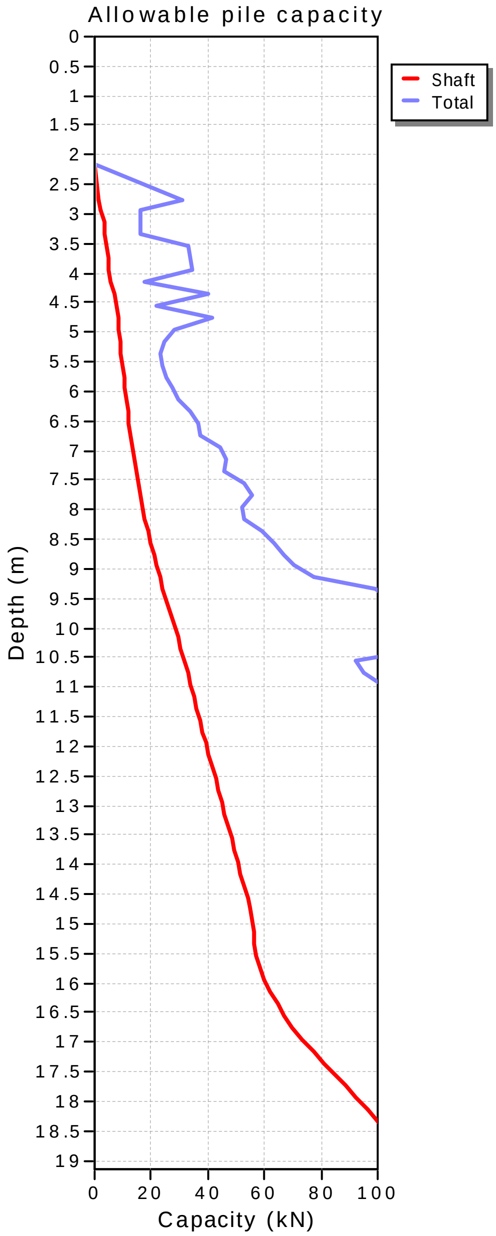
Pile properties

Shaft diameter: 0.10 m
Tip diameter: 0.40 m
Unit friction area: 0.314 m^2
Tip area: 0.126 m^2

Pile shaft Group: Group IA
Pile tip Group: Group II
Pile shaft FOS: 2.00
Pile tip FOS: 2.00







Pile group for bearing capacity factor k_c

- Group I: plain bored piles; mud bored piles; micro piles (grouted under low pressure); cased bored piles; hollow bored piles; piers; barrettes
- Group II: cast screwed piles; driven precast piles; prestressed tubular piles; driven cast piles; jacked metal piles; micropiles (small diameter piles grouted under high pressure with diameter < 250 mm); driven grouted piles (low pressure grouting); driven metal piles; driven rammed piles; jacket concrete piles; high pressure grouted piles of large diameter

Pile group for friction coefficient alpha

- Group IA: plain bored piles; mud bored piles; hollow auger bored piles; micro piles (grouted under low pressure); cast screwed piles; piers; barrettes
- Group IB: cased bored piles; driven cast piles
- Group IIA: driven precast piles; prestresses tubular piles; jacket concrete piles
- Group IIB: driven metal piles; jacked metal piles

121 Rostrevor Street
Hamilton

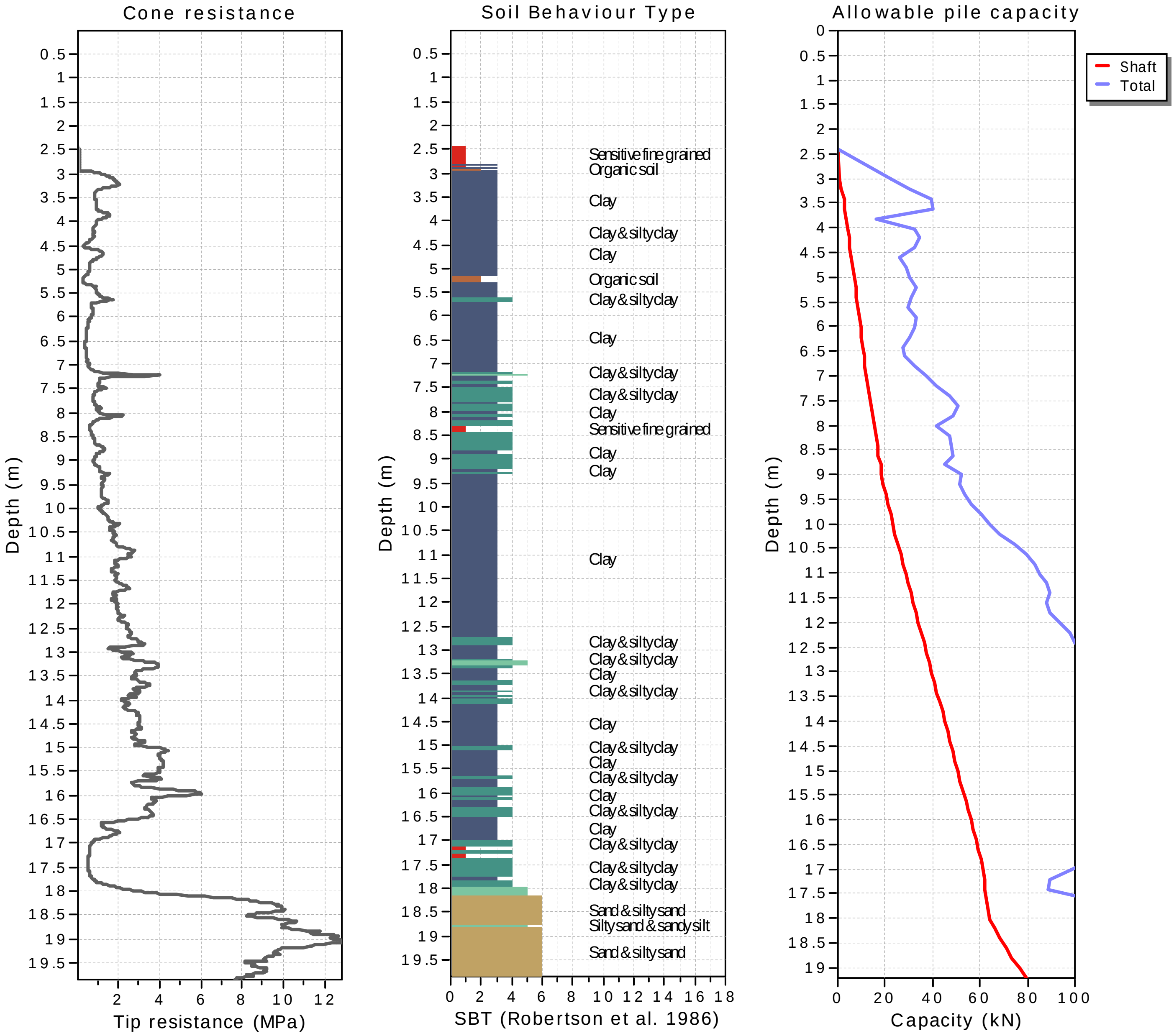
CPT: CPT-03
Total depth: 19.85 m, Date: 20/04/2015
Coords: N -38.01261, E 175.32265
Cone Type: CPTu
Cone Operator: Ground Investigation

Project: Palmer Street Development Stage 1
Location: Palmer Street

Pile properties

Shaft diameter: 0.10 m
Tip diameter: 0.40 m
Unit friction area: 0.314 m^2
Tip area: 0.126 m^2

Pile shaft Group: Group IA
Pile tip Group: Group II
Pile shaft FOS: 2.00
Pile tip FOS: 2.00



Pile group for bearing capacity factor k_c

- Group I: plain bored piles; mud bored piles; micro piles (grouted under low pressure); cased bored piles; hollow bored piles; piers; barrettes
- Group II: cast screwed piles; driven precast piles; prestressed tubular piles; driven cast piles; jacked metal piles; micropiles (small diameter piles grouted under high pressure with diameter < 250 mm); driven grouted piles (low pressure grouting); driven metal piles; driven rammed piles; jacket concrete piles; high pressure grouted piles of large diameter

Pile group for friction coefficient alpha

- Group IA: plain bored piles; mud bored piles; hollow auger bored piles; micro piles (grouted under low pressure); cast screwed piles; piers; barrettes
- Group IB: cased bored piles; driven cast piles
- Group IIA: driven precast piles; prestresses tubular piles; jacket concrete piles
- Group IIB: driven metal piles; jacked metal piles

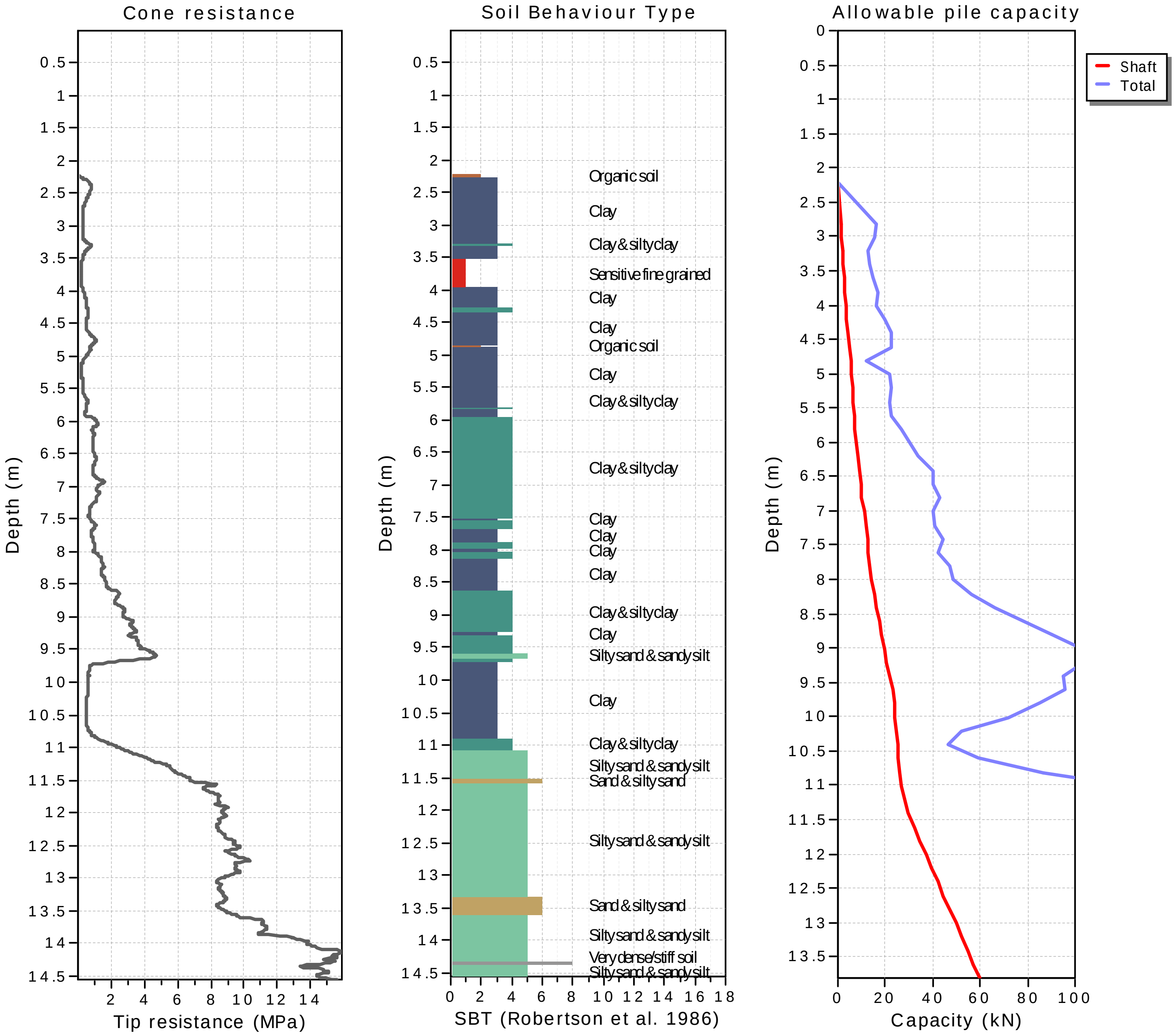
AECOM
121 Rostrevor Street
Hamilton

CPT: CPT-04
Total depth: 14.56 m, Date: 21/04/2015
Coords: N -38.01227, E 175.32362
Cone Type: CPTu
Cone Operator: Ground Investigation

Project: Palmer Street Development Stage 1
Location: Palmer Street

Pile properties

Shaft diameter:	0.10 m	Pile shaft Group:	Group IA
Tip diameter:	0.40 m	Pile tip Group:	Group II
Unit friction area:	0.314 m^2	Pile shaft FOS:	2.00
Tip area:	0.126 m^2	Pile tip FOS:	2.00



Pile group for bearing capacity factor k_c

- Group I: plain bored piles; mud bored piles; micro piles (grouted under low pressure); cased bored piles; hollow bored piles; piers; barrettes
- Group II: cast screwed piles; driven precast piles; prestressed tubular piles; driven cast piles; jacked metal piles; micropiles (small diameter piles grouted under high pressure with diameter < 250 mm); driven grouted piles (low pressure grouting); driven metal piles; driven rammed piles; jacket concrete piles; high pressure grouted piles of large diameter

Pile group for friction coefficient alpha

- Group IA: plain bored piles; mud bored piles; hollow auger bored piles; micro piles (grouted under low pressure); cast screwed piles; piers; barrettes
- Group IB: cased bored piles; driven cast piles
- Group IIA: driven precast piles; prestresses tubular piles; jacket concrete piles
- Group IIB: driven metal piles; jacked metal piles

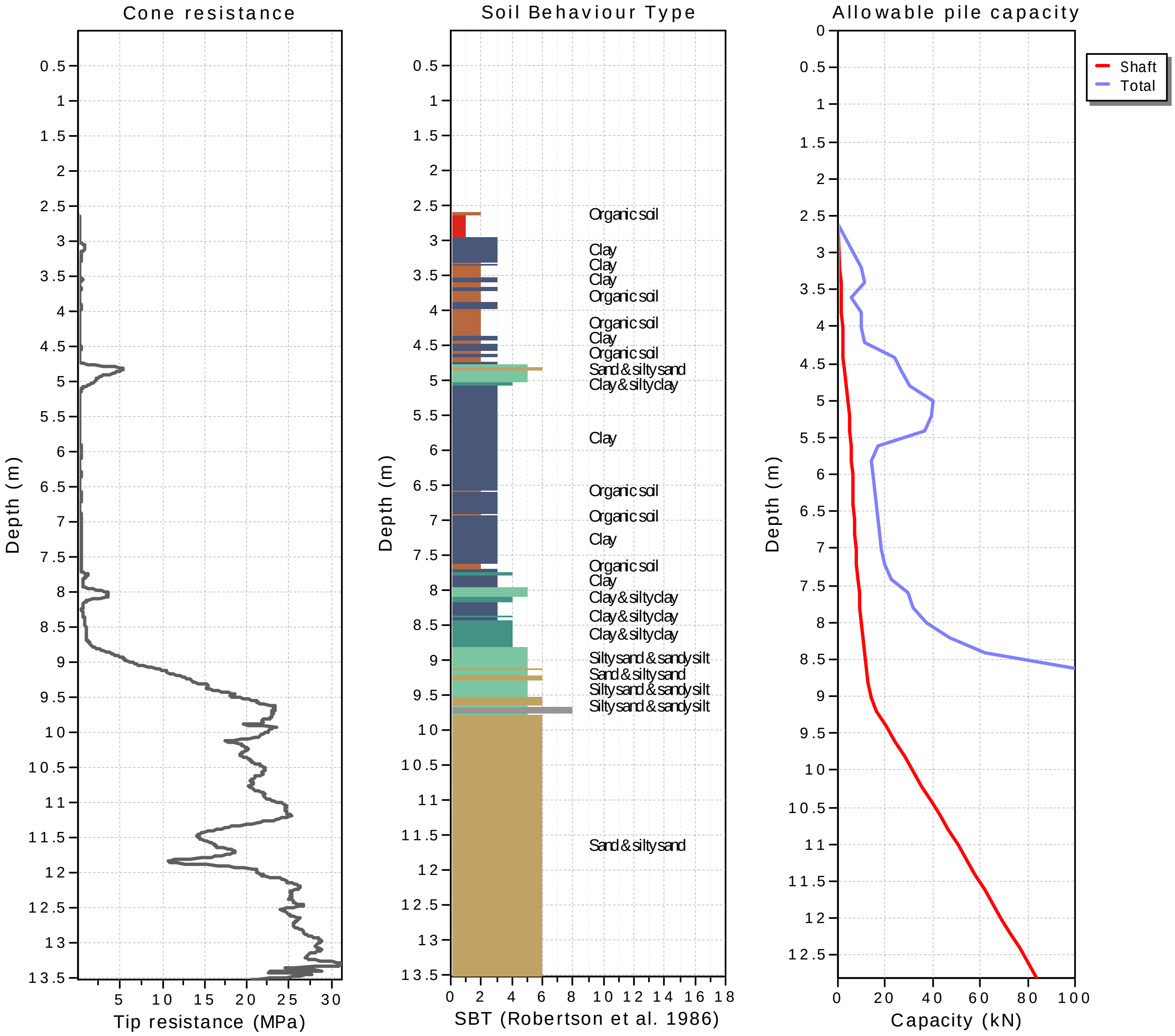
121 Rostrevor Street
Hamilton

CPT: CPT-05
Total depth: 13.52 m, Date: 20/04/2015
Coords: -38.012290, 175.323870
Cone Type: CPTu
Cone Operator: Ground Investigation

Project: Palmer Street Development Stage 1
Location: Palmer Street

Pile properties

Shaft diameter:	0.10 m	Pile shaft Group:	Group IA
Tip diameter:	0.40 m	Pile tip Group:	Group II
Unit friction area:	0.314 m^2	Pile shaft FOS:	2.00
Tip area:	0.126 m^2	Pile tip FOS:	2.00



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